The Taxonomy and Biogeography of the Sea Star genus *Patiriella* in Tasmania.

by

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STATEMENT

Except as stated therein this thesis contains no material that has been accepted for the award of any other degree or diploma in any university and to the best of my belief and knowledge, contains no copy or paraphrase of material previously published or written by another person; except where due reference is made in the text of this thesis.

Alan. J. Dartnall

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CONTENTS.

Appendices

Appendix I. New Zealand Animals in Channel Waters.

Appendix II. Asterodiscus truncatus (Coleman, 1911), a new record for Tasmanian waters.

Appendix III. A Field Key to Tasmanian Sea Stars.

Appendix IV. New Zealand Sea Stars in Tasmania.

Appendix V. A viviparous species of Patiriella from Tasmania.

SUMMARY

An annotated list of the sea star fauna of Tasmania is given and an outline of the history of its investigation provided. The composition of the fauna is considered and although a small number of endemic forms are known its relationships are clearly with south-eastern continental Australia. This compares markedly with the New Zealand Asteroidea of which some 80% are endemic. Also whilst Tasmania and New Zealand possess some 15 genera of asteroids in common only six species are present in both areas.

In Part II the taxonomy of the genus *Patiriella* is considered in some detail. The form of the carinal abactinal plates is included as a diagnostic character for the genus. The genus *Patiriella* is divided into "*regularis*", "*exigua*" and "*gunnii*" groups and *Patiriella gunnii* (Gray) redescribed. A key to the species of *Patiriella* found in Tasmania is provided and geographic and vertical distribution considered.

Some account of reproductive and feeding mechanisms, as far as they have been studied, is offered. An account of morphological variation as it affects choice of taxonomic characters is presented with particular reference to those characteristics offered by H.L.Clark (1946) and the distinction between *Patiriella gunnii* (Gray) and *Patiriella brevispina* H.L.Clark, about which there has been some confusion in the literature.

The biogeography of the genus *Patiriella* in the

Southern Hemisphere is considered in Part III. *Patiriella fimbriata* (Perrier) is considered not to belong to the genus. It is suggested that the genus originated in the Indo-Pacific area and that the greatest proliferation of species has occurred along the east and south coasts of Australia. Hypothetical dispersal routes of forms of *Patiriella* have been constructed.

The family Asterinidae is in great need of revision and familial and generic limits are still undefined in many cases. A prospectus is presented as an aid to future study of the Asterinidae and eventual revision of the family, it being considered that this thesis has laid a basis for further work.

After the main text of this work was completed further information became available, mainly concerning the identity of *Patiriella exigua* (Lamarck) and this is presented in the addenda.

Five papers are bound at the rear of the volume as supporting evidence.

PART I.

THE ASTEROIDEA OF TASMANIA

INTRODUCTION.

Little study has been made of the Asteroidea of Tasmania and the results have been published in widely scattered journals. To make comparisons valid an outline of the sea star fauna of Tasmania and the history of its investigation are presented here.

HISTORICAL ACCOUNT.

Little of the literature deals specifically with Tasmanian asteroid material and the taxonomy and biology of the species found in waters around the state is scattered in numerous papers. The relevant literature can be summarised as follows.

a) The works of H.L.Clark.

Some 37 years span H.L.Clark's working aquaintance with Australian echinoderms. Following his report on the Echinodermata collected by the "Thetis" (1909) Clark contributed papers based on museum holdings and personal collections until in 1938 his "Echinoderms from Australia" was published which included descriptions of many new species and cleared the way for his monographic review "The Echinoderm Fauna of Australia" (1946). In the latter work Clark summarised the information available at that time and, with its consideration of relationships, distribution and origins, it still remains the basic text on echinoderms of the Australian region.

A complete list of H.L.Clark's works, that have been consulted in the course of this study, is presented in the references.

H.L.Clark visited Tasmania in 1929 and on Nov. 15th of that year 'a day was spent dredging in the estuary of the Derwent.' Professor T.T.Flynn, at that time, also presented Clark with a collection of Tasmanian echinoderm material which included Asteroidea. Clark's collecting list for that day (see 1938, p. 572) included the following sea stars.

Tosia aurata	*Patiriella calcar*
Tosia australis	*Patiriella exigua*
Anthenea acuta	*Coscinasterias calamaria*
Asterina scobinata	*Allostichaster polyplax*

H.L.Clark's (1946) list of extant Tasmanian sea star species follows. Synonomies are not given here, the names following Clark's usage.

Astropecten schayeri Doderlein, 1917.

A. vappa Muller and Troschel, 1843.

Radiaster gracilis H.L.Clark, 1916.

Mediaster australiensis H.L.Clark, 1916.

Nectria ocellata E. Perrier, 1876.

Tosia australis Gray,1840.

T. aurata Gray, 1847.

Anthenea acuta Perrier,1869.

Austrofromia polypora H.L.Clark, 1916.

Pseudophidiaster rhysus H.L.Clark, 1916.

Asterina inopinata Livingstone, 1933.

Patiriella calcar (Lamarck, 1816).

Patiriella exigua (Lamarck, 1816).

Henricia hyadesi Perrier, 1891.

Crossaster multispinus H.L.Clark, 1916.

Pedicellaster reticulatus H.L.Clark, 1916.

Coscinasterias calamaria Gray, 1840.

Australiaster dubia H.L.Clark, 1909.

Allostichaster polyplax Muller and Troschel, 1844.

Uniophora sinusoida Perrier, 1875.

Thus, to 1946, twenty-one species or attributed species of Asteroidea were known from Tasmanian waters.

b)

Various systematic works have been published since 1946 that influence any study of Tasmanian Asteroidea.

Notable among them are John's treatment (1948,1950) of Astropecten and A.M.Clark's (1953) revisions of Luidia, Tosia and Pentagonaster.

c) The B.A.N.Z.A.R.E. Asteroidea.

A.M.Clark (1962) studied the collections accruing from Mawson's 1929-31 B.A.N.Z.A.R. expedition. In an appendix, entitled 'Asteroids from southern Australian waters', she listed and commented upon material collected from three stations off Tasmania.

viz.

B.A.N.Z. station 112. Near Cape Maatsuyker, Tasmania.

43° 41' S., 146° 51' E. 84 metres.

B.A.N.Z. station 113. Off Maria Island, Tasmania.

42° 40' S., 148° 27' 30" E. 174-155 metres.

B.A.N.Z. station 115. Off N.E.Tasmania.

41° 03' S., 148° 42' E. 128 metres.

The ten species taken from these stations follow (synonyms shown in brackets after the valid name).

Astropecten pectinatus Sladen, 1883. (A. schayeri Doderlein).

Nectria ocellata Perrier, 1876.

Austrofromia polypora H.L.Clark, 1916.

Pseudophidiaster rhysus H.L.Clark, 1916.

Marginaster species.

Stylasterias reticulata (H.L.Clark, 1916). (Pedicellaster *reticulatus*. H.L.C.)

Australiaster dubius H.L.Clark, 1909.

Coscinasterias calamaria Gray, 1840.

Allostichaster polyplax M. and T., 1844.

A. regularis H.L.Clark, 1928.

Allostichaster regularis H.L.C. was given as a new species record for the state and the genus *Marginaster* recorded for the first time from Australian waters.

A CHECK LIST OF TASMANIAN ASTEROIDEA.

An annotated list of sea stars known from Tasmanian waters to date (1969) follows. The author of each species is given and locality references included. Abbreviations showing storage locations of collected material are:

A.M. The Australian Museum, Sydney, N.S.W.

N.M.V. National Museum of Victoria, Melbourne, Vict.

Q.V.M. Queen Victoria Museum, Launceston, Tasmania.

T.M. Tasmanian Museum, Hobart, Tasmania.

Unless otherwise stated determinations have been made or checked by this author.

(1) *Luidia australiae* Doderlein, 1920.

S.E. Flinders Island, (A.M.)

(2) <u>Astropecten pectinatus</u> Sladen, 1883.

<u>A.schayeri</u> Doderlein, 1917 (in synonomy).

Tasmania (Doderlein, 1917): B.A.N.Z.A.R.E. station 112 (A.M.Clark, 1962): North of Flinders Island- Umitaka Maru station 68.10; Bicheno; Great Taylor Bay, (T.M.): Southport; Gordon, (A.M. as <u>A. schayeri</u>).

(3) <u>Radiaster gracilis</u> (H.L.Clark, 1916).

<u>Mimaster gracilis</u> H.L.C., 1916.

South of Maria Island (Kochler, 1920, Australian Antarctic Expedition).

(4) <u>Mediaster australiensis</u> H.L.Clark, 1916.

Off east coast Flinders Island; Oyster Bay, (collected by F.I.S. Endeavour 1904-1914, A.M. and N.V.M.)

(5) <u>Nectria ocellata</u> Perrier, 1876.

B.A.N.Z.A.R.E. station 113, (A.M.Clark, 1962): Devonport; Bicheno; Rheban; Port Arthur; Bruny Island; Gordon; d'Entrecasteaux Channel, (T.M.): N.E. Cape Pillar (A.M.): Devonport; Oyster Bay, (F.I.S. Endeavour, A.M.): off Devonport and Launceston, (F.I.S. Endeavour, N.M.V.).

There is some doubt about the number and validity of the Australian species of Nectria. A.M.Clark (1966) suggested that *N. ocellata* and *Nectria multispina* H.L.Clark intergrade and that some intermediate forms are indistinguishable from *Nectria pedicelligera* Mortensen, the type and only specimen of which was taken off New Zealand. Shepherd (1967) referred the Tasmanian forms of *Nectria* to *N. ocellata* and *N. multispina* noting the presence of intermediate forms.Miss Clark has now examined a series of specimens from around Tasmania and feels that definition between the species is even more difficult to maintain (A.M. Clark, pers. comm.).

(6) *Pentagonaster dübeni* Gray, 1847.

Georgetown (A.M.Clark, 1953): Gordon; between Southport and Dover (T.M.).

(7) *Tosia australis* Gray, 1840.

Currie Harbour, King Island; Tasmania; Gordon, (Livingstone 1933, A.M.): Tasmania; Georgetown, (A.M.Clark, 1953): King Is.; Fisher Is.; Three Hummock Is.; Hunter Is.; Eddystone Pt.,(A.M.): Boat Harbour; Greens Beach; Binnalong Bay; Devonport; Burnie; Dunalley; Port Arthur; Simpson's Bay; Green Is.; Conningham; Blackman's Bay, Kingston;

Derwent Channel, (T.M.)

(8) Tosia australis forma astrologorum (Müller and Troschel, 1842).

Gordon,(A.M.): Greens Beach; Cape Portland; Stapleton Pt.; off Maria Is.; Green Is.;Great Bay, Bruny Is., (T.M.).

(9) Tosia magnifica (Müller and Troschel, 1842).

Oyster Bay,(F.I.S. Endeavour); Simpson's Bay; Gordon; Hobart; Eddystone Pt.; Mainwaring Cove, West Coast; Tasmania, (A.M.)

Tasmania; Georgetown, (A.M.Clark, 1953. Specimens in the British Museum).

Off Bicheno; Pirates Bay; Simpson's Bay; Green Is.; Gordon; off Middleton; Conningham, (T.M.).

(10) Anthenea acuta Perrier 1869.

Derwent Estuary (H.L.Clark, 1938).

(11) Asterodiscus truncatus (Coleman, 1911).

East coast of Tasmania (Dartnall 1968- see appendix 11. T.M.).

(12) *Petricia vernicina* (Lamarck, 1816).

Cape Portland; near Maria Is.; Rheban; Dunally; d'Entrecasteaux Channel; Gordon, (T.M.): Cape Portland; Simpson's bay, (A.M.).

(13) *Austrofromia polypora* (H.L.Clark, 1916).

Off Maria Is., (H.L.Clark, 1916): Tasmania, (H.L. Clark, 1946): B.A.N.Z.A.R.E. station 113 (A.M.Clark, 1962): off Margate; north of Ragged Head; Fortescue Bay (T.M.).

(14) *Pseudophidiaster rhysus* H.L.Clark, 1916.

Oyster Bay (F.I.S. Endeavour, H.L.Clark, 1916): B.A.N.Z.A.R.E. station 113 (A.M.Clark, 1962).

(15) *Marginaster* sp. indet.

B.A.N.Z.A.R.E. station 113 (A.M.Clark, 1962): Cornelian Bay; River Derwent near Explosives Jetty, (T.M.).

A.M.Clark described a single specimen from off Maria Island as belonging to this genus pointing out that it most nearly resembled *Marginaster paucispinus* Fisher. Recently a series of specimens that can also be attributed this genus were obtained from two littoral stations in the

Derwent Estuary. It remains to be seen whether the B.A.N.Z.A.R.E. specimen is conspecific with the Derwent series.

(16) *Asterina atyphoida* H.L.Clark, 1916.

Green's Beach, north Tasmania, (Q.V.M.).

(17) *Asterina inopinata* Livingstone, 1933.

Tasmania (Livingstone, 1933, A.M.).

(18) *Asterina scobinata* Livingstone, 1933.

Tasmania, (Livingstone, 1933, A.M.): Tasmania, (H.L.Clark, 1946):

Rocky Cape; Cape Portland; Dunalley; Adventure Bay, Bruny Is.; Primrose Sands, Carlton; Red Ochre Beach, near Dodge's Ferry, (T.M.):

Bend Bay, Port Davey (Q.V.M.).

Refer to main text for details of genus *Patiriella*.

(19) *Patiriella calcar* (Lamarck, 1816).

(20) *Patiriella regularis* (Verrill, 1867).

(21) *Patiriella exigua* (Lamarck, 1816).

(22) *Patiriella vivipara* Dartnall, 1969. (Appendix IV).

(23) *Patiriella gunnii* (Gray, 1840).

(24) *Patiriella brevispina* H.L.Clark, 1938.

(25) *Paranepanthia grandis* (H.L.Clark, 1928).

Simpson's Bay; d'Entrecasteaux Channel, (Livingstone, 1933, A.M.): Tasmania; d'Entrecasteaux Channel; Dennes Point, Bruny Is., (T.M.).

(26) *Henricia* species.

East of Ragged Head, Maria Is. (T.M.).

The taxonomy of the genus *Henricia* is complex and until more material comes to hand from Tasmanian waters it appears preferable to attribute this specimen to *Henricia hyadesi* (Perrier) (following H.L.Clark, 1946) or to the *obesa* group of the genus (following A.M.Clark, 1962).

(27) *Crossaster multispinus* H.L.Clark, 1916.

Off Bruny Is. (F.I.S. Endeavour.).

(28) Stylasterias reticulata (H.L.Clark, 1916).

East of Maria Is. (F.I.S. Endeavour, H.L.Clark 1916, 1946): B.A.N.Z.A.R.E. stations 113 and 115, (A.M.Clark 1962).

(29) Astrostole scabra (Hutton, 1872).

Binnalong Bay; the Gulch, Bicheno; Beaching Bay, Maria Is.; Fossil Is., Eaglehawk Neck; Variety Bay; Adventure Bay; Kingston; Cape Direction; Pierson's Pt. (T.M.).

See appendix III and V.

(30) Coscinasterias calamaria Gray, 1840.

Cape Portland; off Bicheno; 2 miles S. of Refuge Is.; Coles Bay; Eaglehawk Neck; Port Arthur; Dunalley; Barnes Bay, Bruny Is.; Green Is.; off Kalora, Derwent Channel; Conningham; Carlton Beach; Roches Beach; Taroona; Sandy Bay; Hobart Docks. (T.M.).

(31) Australiaster dubius (H.L.Clark, 1909).

Near Tasmania, (H.L.Clark, 1909, 1946): B.A.N.Z.A.R.E. stations 113 and 115 (A.M.Clark, 1962):

Fortescue Bay; east of Green Is.; off Pedra Blanca,(T.M.).

(32) <u>Allostichaster polyplax</u> (Müller and Troschel, 1844).

Tasmania (H.L.Clark,1946): B.A.N.Z.A.R.E. station 115 (A.M.Clark, 1962): near Burnie; Greens Beach; Cape Portland; Binnalong Bay; Dunalley; Fossil Is., Eaglehawk Neck; Roches Beach; Ralph's Bay; Green Is.; Variety Bay; d'Entrecasteaux Channel. (T.M.)

(33) <u>Allostichaster regularis</u> H.L.Clark, 1928.

B.A.N.Z.A.R.E. station 113 and 115, (A.M.Clark, 1962): Cape Portland (T.M.).

(34) <u>Uniophora sinusoida</u> Perrier 1875.

Tasmania, (Perrier, 1875 in Clark, 1946): Cape Portland; Flinders Is.; Derwent Channel; Green Is.; Tasmania; Roches Beach; Taroona, (T.M.).

Shepherd (1967) has placed this species in the synonomy of <u>Uniophora granifera</u> Lamarck. I cannot accept this opinion, at this time, because even the small Tasmanian samples do not come within Shepherd's recorded range of variation and thus retain H.L.Clark's (1946) grouping.

THE COMPOSITION OF THE TASMANIAN ASTEROID FAUNA.

To date, the Asteroidea of Tasmania comprise thirty-four species, attributed species or *forma*.

One species (*Patiriella regularis* (Verrill)) must be excluded from any consideration of the composition of the fauna as evidence suggests that this form is a recent immigrant (see section on distribution and appendix I and V).

The thirty-three species remaining are included in twenty-four genera. Ten genera are probably deep water forms sometimes extending upwards onto the continental shelf. The remaining genera include littoral and shallow water forms - again with individuals extending the range into greater depths.

Few species can be regarded as endemic with any certainty. The undetermined species of *Marginaster* reflects the general situation of deeper water forms, the evidence being too meagre to elucidate true distributional data. Among littoral and shallow water species the evidence is little more conclusive. *Asterina scobinata* Livingstone, *Patiriella vivipara* *mihi* and the littoral *Marginaster* forms appear to be restricted to the Tasmanian littoral.

Bennett and Pope's (1960) concept of a cool Maugean province extending around the shores of Tasmania with an overlapping area between warm and cool temperate zones in the north is used as a basis for distributional comparisons later in this account. It suffices here to state that as far as the Asteroidea are concerned only four species can be considered Maugean province endemics so far.

viz.:- *Tosia australis* (see Bennett and Pope, 1960, p.212.), *Asterina scobinata*, *Patiriella vivipara* and, perhaps, a species of *Marginaster*.

Of the remaining littoral and shallow water species most are common to the south and south-eastern edge of the Australian continent and anomalies in distribution will probably be found to be due to behavioural and ecological modifications at the southern end of the ranges of the animals concerned.

THE NEW ZEALAND SEA STAR FAUNA.

Fell (1947) has analysed the 'constitution and relations of New Zealand echinoderm fauna' in some detail. He demonstrates a high proportion of endemic species (c. 80%) and states that 29 species (16% of the total) comprise Australian and Indo-Pacific species. Of the Tasmanian Asteroidea some 15 genera and 6 species are common to both Tasmania and New Zealand including amongst others the widespread *Allostichaster polyplax* (W.A., S.A., Vic., Tas., N.S.W., and N.Z.) and *Astrostole scabra* (see appendix V).

PART 11.

THE GENUS PATIRIELLA IN TASMANIA.

PREAMBLE.

This study attempts to review and complement the knowledge of the asterinid sea-star genus *Patiriella* in the area comprising the littoral and shallow waters of Tasmania and the adjacent islands. Some comparisons are drawn from material from outside this area (i.e. within Australia) and later some considerations of the genus in the Southern Hemisphere are presented. In conclusion a prospectus for future study of the family Asterinidae is given based on the information and experience gained in the course of this study.

SYSTEMATIC ACCOUNT.

NOMENCLATURE.

Valid names.

a) *Patiriella calcar* (Lamarck, 1816).

b) *Patiriella regularis* (Verrill, 1867).

c) *Patiriella exigua* (Lamarck, 1816).

d) *Patiriella vivipana* Dartnall, 1969.

e) *Patiriella gunnii* (Gray, 1840).

f) *Patiriella brevispina* H.L.Clark, 1938.

Common Names.

Asteroids of the same general form as the species of Patiriella are often referred to as cushion stars. Patiriella calcar is often referred to, in Tasmania, as the "garden starfish", a reference to its pretty colours and the fact that it is often found in attractive rock pools. There does not appear to be a specific vernacular for any one of the species such as "sea bat" for Patiria miniata Brandt from North America.

TAXONOMY.

Suprageneric affinities.

Phylum	ECHINODERMATA
Subphylum	ASTEROZOA
Class	STELLEROIDEA
Subclass	ASTEROIDEA
Order	SPINULOSIDA
Family	ASTERINIDAE
Subfamily	ASTERININAE

The sea star family Asterinidae is cosmopolitan in its distribution (Hyman, 1955, pp. 336-337). The family contains a superficially heterogeneous assortment of forms distinguished from the other spinulose families by the presence of well developed actinal plates, small mouth plates, and narrow ambulacral furrows. The abactinal skeleton is composed of imbricating plates usually bearing spines, spinelets or paxillae; the actual skeleton is also formed of imbricate plates carrying tufts of spines or one, two or three spines only.

The family Asterinidae in Australia contains nine attributed genera. There is a great diversity of form ranging from the nearly pentagonal to the attenuated star and the many forms exploit a wide range of habitats. The nine Australian genera may be separated by H.L.Clark's key (1946, p. 129).

Three of the genera listed by Clark are found in Tasmania; *Asterina*, *Paranepanthia* and *Patiriella*, the genus under discussion. One species of the genus *Nepanthia* ranges from Western Australia to Victoria (Shepherd 1968, p. 749) and if its distribution parallels that of *Austrofromia polypora*, *Patiriella calcar*, *Patiriella brevispina* and *Patiriella gunnii* it might be expected to be present near the northern coast of Tasmania.

The Genus.

Genus *Patiriella* Verrill.

Verrill, A.E., 1913 - *American Journal of Science*, Series 4., vol. 35, pp.480, 483.

Genotype: Patiriella (Asterina) regularis (Verrill, 1867).

Diagnosis of genus.

Asterinid sea stars with the abactinal plates of the papular areas of two or more kinds, the larger proximally ordered or lunate and notched for the passage of papulae. Between these plates are groups of small ovate or pyriform ossides (fewer than in the genus Patiria) mostly bearing small, rounded clusters of spinules. Internal vertical pillars present in interradial areas. Actinal plates with a large solitary spine or sometimes two (following Verrill 1913 pp. 479-480).

Comments.

Verrill erected the genus to contain, apart from the type species, Patiriella exigua* (Lamarck), Patiriella calcar* (Lamarck), Patiriella fimbriata* (Perrier), Patiriella squamata (Perrier), Patiriella calcarata* (Perrier), Patiriella pusilla (Perrier) and Patiriella gunnii* (Gray). The species marked (*) are currently accepted as belonging to the genus though Madsen 1956 records his doubts about the generic placing of P. fimbriata.

It is the opinion of this author that, on the characteristics of the carinal abactinal plates, *P. fimbriata* should be removed from the genus. This opinion is based on the observation that in *Patiriella* the carinal row of plates on the abactinal surface of each ray is doubly notched for papulae, a characteristic not shared by the asterinid species *fimbriata*.

A modified generic diagnosis is offered.

Asterinid sea stars with a plane actinal surface. The plates of the actinal intermediate and abactinal papular areas imbricate. The carinal row of of abactinal plates of each ray doubly notched for papulae; the remaining plates singly notched and with their free end exposed, appearing crescentic. Secondry ossicles present. Abactinal plates carry groups of short spinules on the free edge. Actinal intermediate plates rarely carry more than two spines. Oral plates rarely bearing more than two suboral spines; usually one or none. Pedicellariae absent.

The neighbouring genera.

In Tasmania the only genera with which *Patiriella* may be confused are *Asterina*, *Paranepanthia* and *Marginaster*.

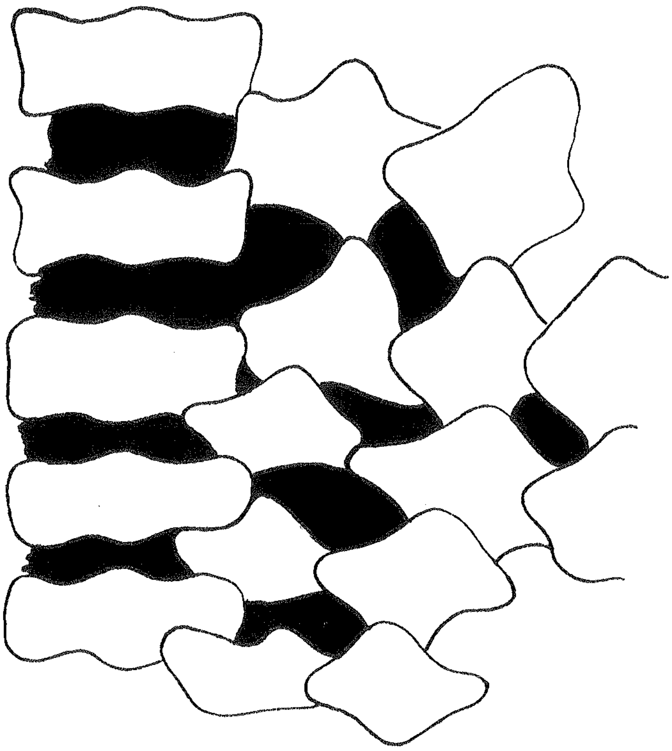
The poraniid *Marginaster* may be distinguished by the thick skin which envelopes the body which is superficially asterinid in form; *Paranepanthia* by the form

Fig.1.

Doubly notched carinal, abactinal plates of _Patiriella_.

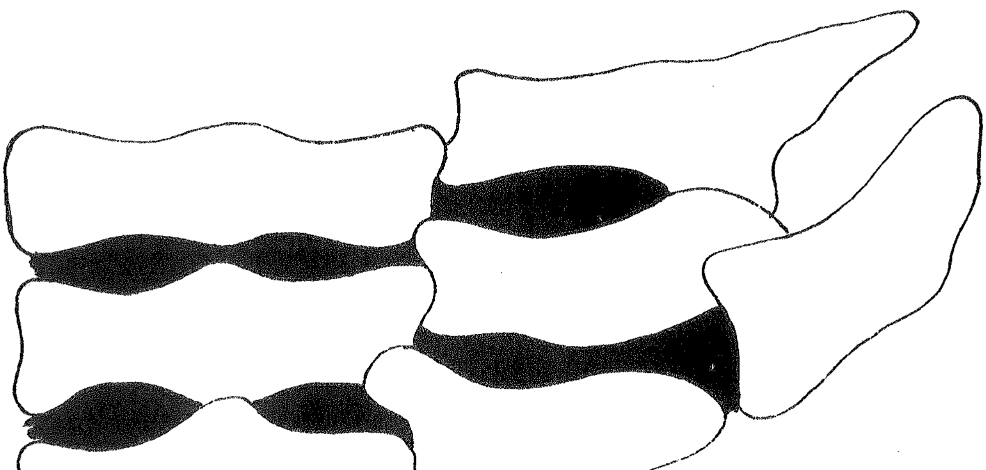
a) Patiriella gunnii.

b) Patiriella calcar



a

b



and spinulation of the interradial abactinal plates and *Asterina* by its multispined actinal and oral plates and the form of the carinal series of plates. It is considered that the doubly notched carinal plates observed in the species of *Patiriella* provide a reliable taxonomic characteristic and a diagrammatic representation of these characteristics is offered (fig. 1).

The Tasmanian species of *Patiriella*.

The Tasmanian species of *Patiriella* may be divided into three groups.

a) The "*regularis*" group. Species of *Patiriella* with single spines on the actinal intermediate plates; with free swimming larvae and upwardly directed gonophores.

b) The "*exigua*" group. Species of *Patiriella* with single spines on the actinal intermediate plates; rarely attaining more than 14 mm R; shortened larval development either attached to the substrate or within the body of the adult. Larvae not free swimming.

c) The "*gunnii*" group. Species of *Patiriella* with paired spines on the actinal intermediate plates; with six rays; free swimming larvae and upwardly directed gonopores.

N.B. The lists of material examined are not the entire lists of material that has been handled; the lists enumerate the specimens used to formulate the descriptions.

a) "regularis" group.

1. Patiriella regularis (Verrill, 1867).

Synonomy.

Asterina (Asteriscus) regularis Verrill, 1867.

Asterina cabalistica Lütken, 1871.

Asterina regularis Hutton, 1872; Perrier, 1875; Hutton, 1878; Farquhar, 1895; 1897, 1898; Benham, 1909.

Patiriella regularis Verrill, 1913; W.K.Fisher,1919; Koehler, 1920.

Asterina (Patiriella) regularis Mortensen, 1925.

Patiriella mimica Livingstone, 1933.

Asterina regularis Fell, 1952, 1959.

non. Asterina regularis F.Jeffr.Bell, 1884.

Type specimens: Presumably in the Museum of Yale College, U.S.A.

Type locality: Aukland, New Zealand.

Description of species.

A five rayed, stellate form; R:r = 1.5/1.8 : 1 in Tasmanian samples. Largest specimen recorded R = 4.3mm.

The actinal surface is plane. The abactinal skeleton consists of papulate and apapulate plates. The abactinal spinulation is close being confined to, or more prominent on the crescentic edges of the plates giving a regularly patterned appearance.

The madreporite is subrounded, being some 3.5mm across in specimens of c.30 mm R; it is channelled and perforate.

The anus is centrally placed and surrounded by a ring of inclined spines.

The inferomarginal plates and their spinulation form a fringing edge to the body. The actinal plates are imbricate and carry a single spine except towards the margin where each plate may carry two spines, very rarely three.

The adambulacral plates bear two furrow spines and one subambulacral spine. The oral plates carry five oral spines, decreasing in size away from the mouth. A characteristic large suboral spine is present on each oral plate which may be slightly curved or horn-like. (cf. Mortensen, 1925 and fig. 2).

The gonoduct opens abactinally.

Colour.

Live individuals of *P. regularis* are usually unicoloured on the abactinal surface. Shades of green, brown, reddish/brown and yellow/brown are found. The actinal surface is off white.

Material examined.

Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H421	17	Blackman's Bay	1. Xl. 1952	V.V.H.
H430	65	Oyster Cove	18. Xl. 1952	V.V.H.; E.R.G.
H432	40	Wrest Point	6. V. 1954	D.A.
H429	3	Blackman's Bay	5. lV. 1955	V.V.H.
H431	39	Ralph's Bay	6. lV. 1955	E.R.G.
H352	4	Ralph's Bay	28.Vlll.1959	V.V.H.
H118	6	Sandy Bay	20. Xl. 1964	E.A.
H256	9	Sandy Bay	Feb. 1966	E.A.
H.258	1	Roches Beach	14.111. 1966	---

Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H395 H439	19	Risdon	1. V. 1966	A.J.D.
H427	21	Hobart Dock	17. V. 1966	A.J.D.
H426 H438	35	Conningham	29. V. 1966	A.J.D.
H440	10	Sandy Bay	9. VI. 1966	A.J.D.
H269	3	Midway Point	11. VI. 1966	A.J.D.
H271	52	Conningham	13. VI. 1966	P.G.; J.G.
H339	8	Oyster Cove,Kettering	1. IX. 1966.	A.J.D.
H425	11	Conningham	16. X. 1966	A.J.D.

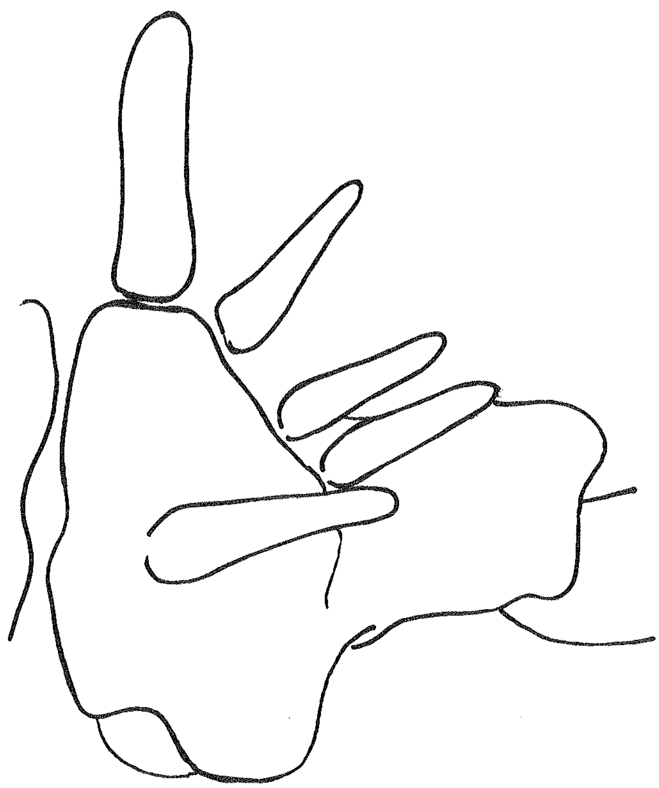
Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H272	7	Tooroona	16. X. 1966	J.A.D.
H342 H326	6	Variety Bay	30. 1. 1967	A.J.D.; J.G.
H433	1	Tinderbox	12. IV. 1967	E.A.
H340	3	Conningham	14. IV. 1967	A.J.D.
H341	2	Oyster Cove, Kettering.	14. IV. 1967	A.J.D.
H319	1	Margate	19. IV. 1967	H.L.
H347	56	Tooroona	19. IV. 1967	A.J.D.; J.G.
Total	420			

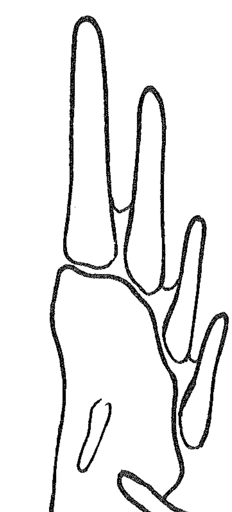
Fig.2.

Oral plate and spines of _Patiriella regularis_.

Fig.3.

Oral plate and spines of _Patiriella calcar_.





2. *Patiriella calcar* (Lamarck, 1816).

Synonomy.

Asterias calcar Lamarck, 1816.

Asterina calcar Gray, 1840; McCoy, 1890.

Patiriella calcar Verrill, 1913; H.L.Clark, 1938, 1946; Shepherd, 1968.

Type specimens: Paris (unconfirmed).

Type locality: Australia.

Description of species.

Disc large with 7 - 11 rays, usually 8 (fig.). R : r = c.1.5 : 1 in Tasmanian material.

Actinal surface plane.

Slightly heavier in form than the preceding species and with more dense spinulation on the crests of the crescentic plates giving the animal a characteristic pattern only paralleled by large specimens of *Patiriella regularis* and *Patiriella brevispina*.

Actinal spines usually one per plate. Two furrow and one subambulacral spine. Oral plates carry 3 - 4 oral spines and each oral plate may carry 0, 1, or 2 suboral spines. (fig. 3)

The gonoduct opens abactinally.

Colour.

Patiriella calcar is renowned for the wide range of colours and the complexity of patterns illustrated. Purple, red, orange, blue, blue/green, buff and white tints are common in varied combinations. Often the predominent colour of the disc is repeated as a concentric band or bands on the rays, a ring or rings of another colour interpolated in the intervening areas.

The actinal surface is consistently off white.

Comments.

H. L. Clark (1946) used, among other characters, the absence of suboral spines to distinguish *Patiriella calcar*, *Patiriella gunnii* and *Patiriella brevispina* from other members of the genus. The presence or absence of suboral spines is not a reliable feature of Tasmanian material and further details are given when morphological variation is considered.

Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H314	2	Safety Cove	21. IV. 1946	J.S.
H100	1	Taroona	3. IX. 1964	J.T.G.
H237	4	Roches Beach	1965	---
H355	33	Resolution Ck. Bruny Is.	1. IX. 1966	A.J.D.
H273	1	Dodges Ferry	17. IX. 1966	J.T.
H420	6			
H422	3	Roches Beach	15. X. 1966	A.J.D.
H437	4			
H356	5	Taroona	16. X. 1966	J.A.D.

Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H320	2	Black Rocks	5. I. 1967	J.G.
H327	41	Bay of Fires		
H328	12	2 m. N. of Scamander	6. I. 1967	A.J.D.
H388	1	Shelly Beach	30. I. 1967	D.A.
H312	1			
H330	15	Variety Bay	30. I. 1967	A.J.D.; J.G.
H331	12			
H329	28	Taroona	March, 1967	A.J.D.
H313	4	Primrose Sands	2. IV. 1967	E.A.
H396	3	Boat Harbour	10. VI. 1967	A.J.D.

Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H321	3	Wynyard	12. VI. 1967	A.J.D.
H325	4	Blackman's Bay	16. VI. 1967	D.V.
H451	5	Binnalong Bay	Feb. 1968	R.S.
H466	4	Cape Portland	2.III. 1969	A.J.D.
Total	194			

b) "exigua" group.

3. *Patiriella exigua* (Lamarck, 1816).

Synonomy.

Asterias exigua Lamarck, 1816.

Asterias minuta de Blainville, 1834.

Asterias minuta Nardo, 1834; Agassiz, 1834; Gray, 1840.

Asterina kraussii Gray, 1840.

Asteriscus pentagonus Müller and Troschel, 1842.

Asterina kraussii M. and T., 1842; Gray, 1866.

Asterina pentagona von Martens, 1866.

Asterina exigua Perrier, 1876; Koehler, 1910.

Patiriella exigua Verrill, 1913.

Asterina exigua H.L.Clark, 1921.

Patiriella exigua H.L.Clark, 1938, 1946; Shepherd, 1968.

Type specimens: In Paris (no confirmation).

Type locality: Cape of Good Hope.

Description of species.

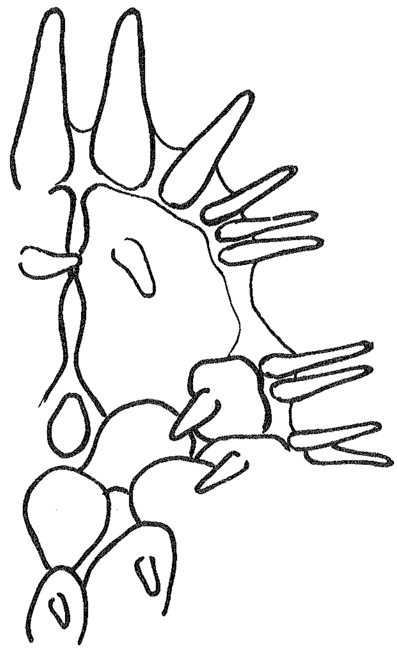
A small, pentagonal asteridid sea star. Four

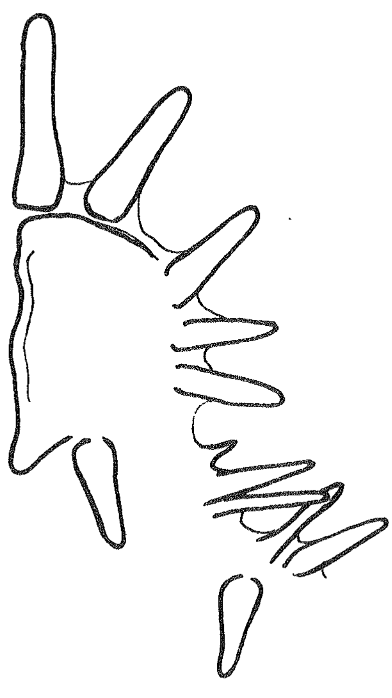
Fig.4.

Oral plates and spines and proximal actinal skeleton of *Patiriella exigua*.

Fig.5.

Oral plates and spines of *Patiriella gunnii*.





and six-rayed individuals are not uncommon; seven armed forms are encountered more rarely.

R : r = c. 1.2 : 1. The largest size recorded in Tasmanian material is 22 mm. R. This size is exceptional, 14- 15 mm. R being the largest size commonly met.

The actinal surface is plane. The abactinal surface is made up of imbricate plates of typical fascies.

The madreporite is rounded but not symmetrical being c. 1.2 mm. across the axis in line with the radius of the animal in individuals of c. 12 mm. R.

The madreporite is channelled and perforate. The anus is minute, just eccentric of the centre of the disc, and surrounded by inclined spines.

The inferomarginal plates and their spinelets form a fringing border to the animal. the actinal intermediate plates are imbricate and carry a single spine. Within the angle of the mouthplates spines may be absent. The adambulacral plates carry two furrow spines, sometimes three proximal to the mouth plates, and a single subambulacral spine.

The oral plates carry 5 - 6 oral spines, the two innermost being larger than the following series; a single suboral spine is present on each oral plate. (fig. 4)

The gonoducts open actinally near the oral plates.

Colour.

There is little variation in the colour of live specimens observed in Tasmania. The abactinal surface is light brownish-green; the ground colour being green with the brown colour restricted to the crescentic areas of the abactinal plates. Colour variation includes the brown areas becomming more red in colour and the ground colour ranging through green, blue and,in some cases, purple.

The actinal surface is consistently blue/green.

Material Examined.

Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H211	6	Hobart	20. II. 1909	Anon.
H212	3	Roaring Beach, Port Davey	Feb. 1937	C.D.
H222	12	Stanley	Oct. 1937	A.W.G.P.
H210	2	Bellerive	Jan. 1939	D.C.P.
H424	5	Oyster Cove, Kettering	18. XI. 1952	E.R.G.; V.V.H.
14491/H21	2	Blackman's Bay	22.III. 1957	B.J.N.
14492/H22	2	Hope Beach	12. IV. 1957	B.J.N.
14493/H23	1	Point Puer	16. IV. 1957	B.J.N.
14506/H24	1			

Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H198	8	Blue Lagoon, Dodges Ferry	17. I. 1963	B.C.M.
H174	7	Dunally	30. VI. 1965	C. and P.
H271	2	Conningham	13. VI. 1966	P.G.; J.G.
H434	4	Policeman's Point	26. VI. 1966	A.J.D.
H441	13	Simpson's Bay, Bruny Is.	4. I. 1967	D.
H345	2	Murdunnah	12. I. 1967	A.J.D.
H336	33	Shelly Beach	30. I. 1967	D.A.
H387	15			
H338	17	Tinderbox	12. IV. 1967	E.A.
H382	36	Nubeena	14. V. 1967	L.J.

Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H397	10	Boat Harbour	10. VI. 1967	A.J.D.
H315	4	Rocky Cape	11. VI. 1967	A.J.D.
H349	17	Port Arthur	20. VI. 1967	A.P.A.; E.A.
H366	6	Trial Harbour	4. XI. 1967	A.J.D.
H452	4	Maria Island	15. IV. 1968	A.J.D.
H455	4	Granite Point	15.VIII.1968	E.H.
H453	13	East Sandy Cape	18.VIII. 1968	E.H.
H454	19	Cape Portland	18.VIII.1968	E.H.

Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H456	4	Swan Island	Sept. 1968	F.L.S.
H458	7	Cape Portland	2.III. 1969	A.J.D.
Total	257			

4. Patiriella vivipara Dartnall, 1969.

Synonomy: none.

Type specimens: Holotype and paratype series housed in the Tasmanian Museum.

Type locality: Midway Point, Pittwater, Tasmania.

Diagnosis.

A small, orange yellow asterinid so far known only from S.E. Tasmania. Viviparous (see section and appendix V).

Description: Proc. Linn. Soc. N.S.W., 93 (3) : 294 - 296, Pl. XXIX (included as appendix V).

c) "gunnii" group.

5. Patiriella gunnii (Gray, 1840).

Synonomy.

Asterina gunnii Gray, 1840. (Being a restriction of Asterias calcar, var. b, Lamarck, 1816); Gray, 1866; Perrier, 1875; McCoy, 1890.

Patiriella gunnii Verrill, 1913; H.L.Clark, 1928, 1938, 1946.

Patiriella gunnii A.M.Clark, 1966; Shepherd, 1968.

Comments.

Clark (1966) presumably followed Article 14c of the Rules of Zoological Nomenclature concerning the genitive of modern patronymics and Article 19 concerning typographical errors, *lapsus calami* and errors of transcription. However, Miss Clark has given no evidence of any of these errors so that it appears that the rulings concerning customary usage apply and the specific name *gunnii* must be retained (see Article 19 and summary 8 of Opinions Rendered. Schenk and McMasters, 1936).

Type specimens: located in the collections of the British Museum.

Type locality: Sandy Bay, Hobart, Tasmania.

Through the kind offices of Miss A.M.Clark, the Director and Trustees of the British Museum, (Natural History) made four of Gray's *Patiriella gunnii* specimens available for redescription. Miss Clark states that an earlier series of specimens registered in 1840 are most probably Gray's original types and not the Georgetown series as stated in A.M. Clark, 1966, p.320.

Gray repeated his description in 1866 and one of the earlier series was made available as a lectotype and three of the Georgetown series as paralectotypes.

Lectotype: British Museum Reg. No. 40.3.9.-10.
Loc. Sandy Bay, Hobart Town.

Paralectotypes: B.M. Reg. No's 49.11.19.-10-14-33.
Loc. Georgetown, Tasmania.

Description of Lectotype.

Specimen 40.3.9.-10.; R = 22 mm., r = 16 mm., r : R = 1 : 1.37, vh = 6 mm.

A six rayed, asterinid sea star markedly flattened; the actinal surface plane and with a very acute marginal angle.

The abactinal surface is paved with imbricating plates of two kinds. Those of the rays, the disc and most of the abactinal intermediate areas are crescentic at their free edge allowing the passage of papulae. The plates of the carinal row running along the abactinal axis of each ray are doubly notched allowing the passage of two rows of papulae.

The plates of the interradial, abactinal areas near to the margin are smaller and non papulate. Small secondary plates are present between the larger papular plates.

The exposed surfaces of the abactinal plates are crowned with groups of small, blunt, thorny spinelets, some twenty-eight spinelets being present on the larger plates near to the centre of the disc and six to eight spinelets on the plates near to the margin.

The madreporite is rounded, channelled and perforate and situated interradially some 3 mm. from the centre of the disc. The anus is not visible in the lectotype.

The superomarginal plates are not distinct from the succeeding rows of abactinal plates. The inferomarginal plates form the edge of the body and each carries a fringing group of 7 - 9 spinelets.

The actinal surface between the ambulacra is paved with imbricate plates. The largest chevron of plates, reaching from the tip of each ray to the mouth plates, carries one spine on each plate. The succeeding three inner chevrons of plates carry one spine on each plate for about the proximal half of the chevron and the remainder of the actinal intermediate plates two spines except towards the disc margin where some plates may carry three spines.

In the lectotype each adambulacral plate bears a single subambulacral spine and a pair of furrow spines. Furrow spines may be grouped in threes towards the mouth and singly

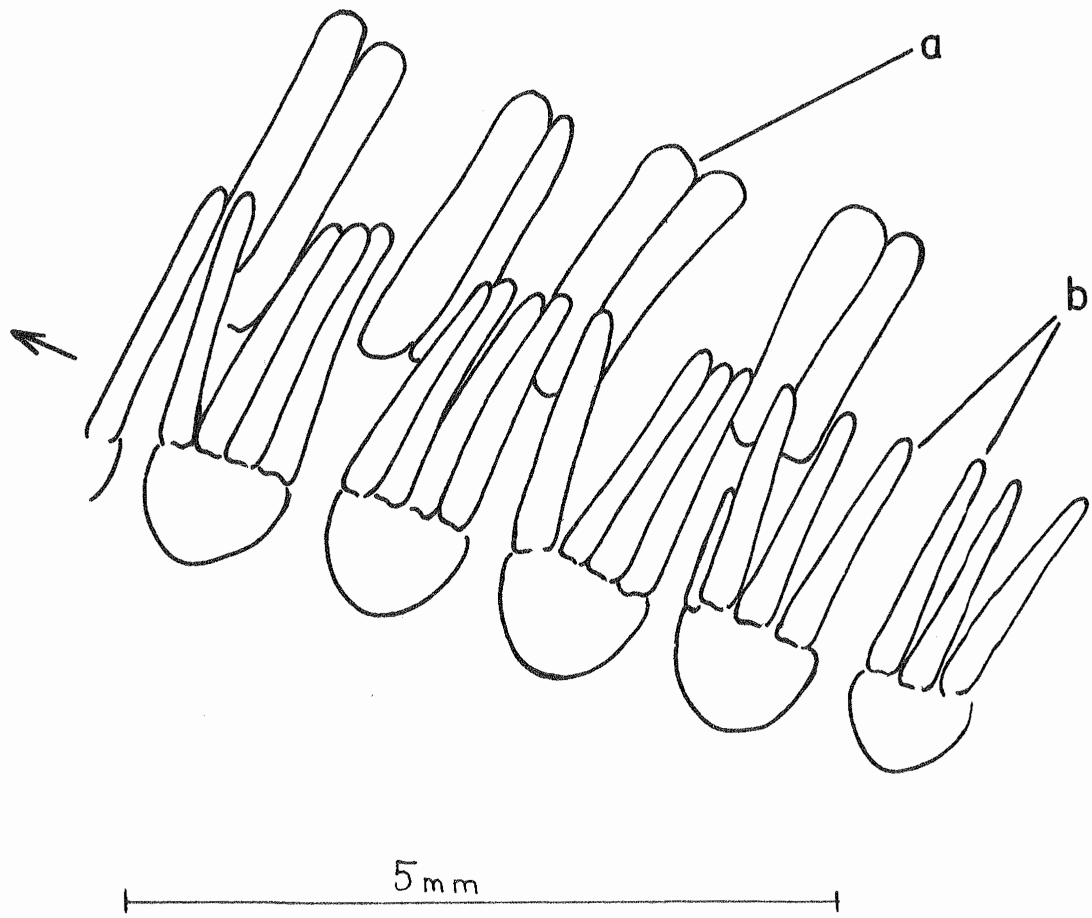
Fig.6.

Subambulacral and furrow spines of Patiriella gunnii

a) subambulacral spines.

b) furrow spines.

The arrow is directed orally.


a
b
5mm

towards the tip of the rays.

Each oral plate bears five oral spines, the innermost being the largest. The oral plates of the lectotype bear no suboral spines.

Pedicellariae are absent.

Species diagnosis for *Patiriella gunnii* (Gray).

A six rayed form of *Patiriella* more flattened than the following species. The adambulacral plates are more likely to carry groups of three or more furrow spines than *P. brevispina* and in many cases the subambulacral spines are diplacanthid (fig. 6). (For further discussion of this diagnosis and the basis upon which these characteristics were selected see the section on variation.)

Colour.

Specimens collected in Tasmania have all been mottled purple on the actinal surface. The colour of the actinal surface is off white. Shepherd(1968) comments upon the diversity of colour and states that the species "appears in mottled shades of red, pink, blue, light brown or cream". Orange and dull purple colouration were noted in one series of specimens from Victoria. (National Museum of Victoria Reg. No's. 76/01, 69/10.)

Material examined.

Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H423	2	Maria Island	28. IV. 1967	D.W.
---	1	Primrose Sands	6. XI. 1967	E.A.
H459	1	Cape Portland	2.III. 1969	A.J.D.
Total	4			

6. *Patiriella brevispina* H.L.Clark, 1938.

Synonomy. None.

However, A.M. Clark (1966) on publishing the results of the "Echinodermata" from the Port Phillip Survey noted that at least one of the specimens received was dull purple "dorsally" (my inverted commas) when received. *Patiriella brevispina*, as recognised by this author, is common in Port Phillip Bay and realising the difficulty in identifying the Port Phillip material adequately from preserved specimens A.M. Clark lumped the samples under the heading of *Patiriella gunnii* probably inadvertently ignoring a prominent member of the fauna.

Until proven otherwise it appears unwise to create a synonym, viz. *P. gunnii* (part)., but the likelihood should be remembered.

Type specimens: Holotype in the Museum of Comparative Zoology, Harvard, U.S.A. One paratype in the collections of the Australian Museum, Sydney (Reg. No. J6181).

Type Locality: Koombana Bay, Bunbury, W.A. 5- 8 fathoms.

Description: see H.L.Clark, 1938, p. 166, pl. 22, figs. 2, 3.

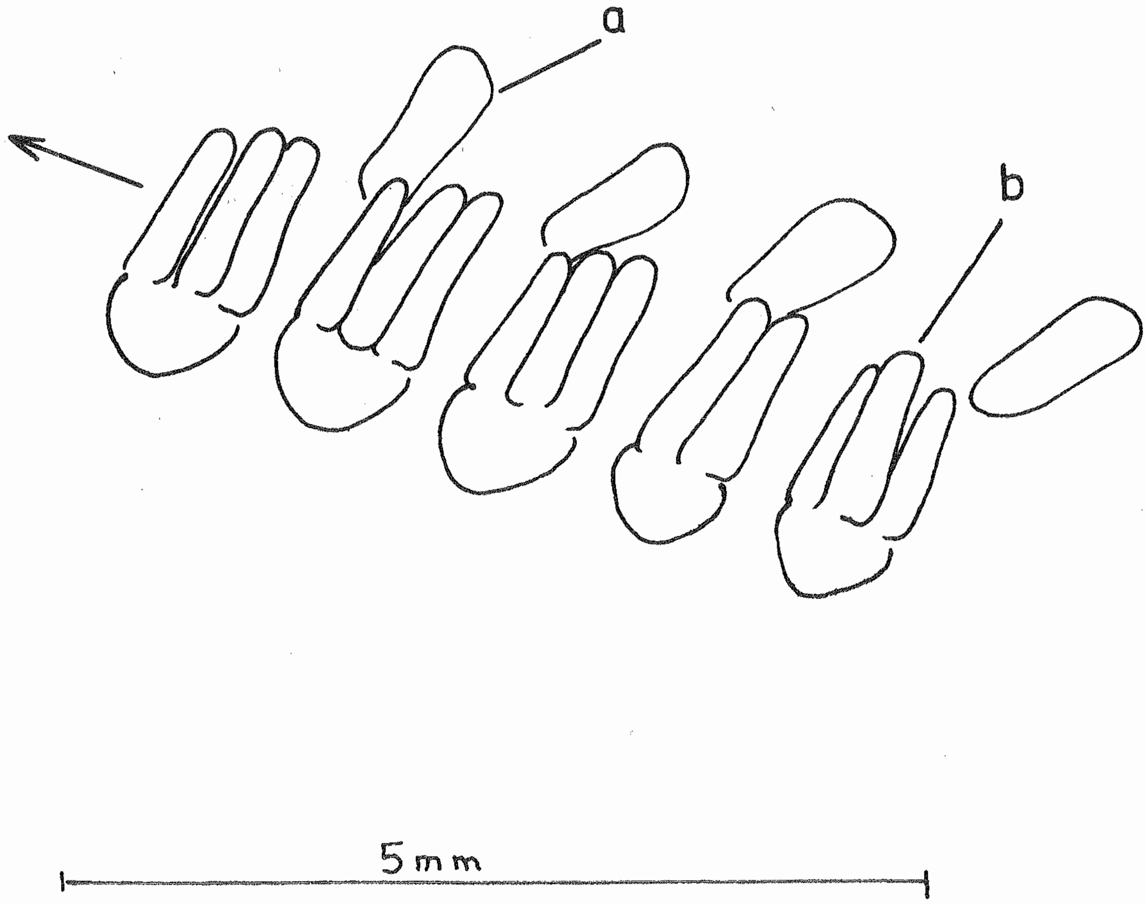
Fig.7.

Subambulacral and furrow spines of *Patiriella brevispina*.

a) subambulacral spine.

b) furrow spine.

The arrow is directed orally.


a
b
5mm

Diagnosis.

A six rayed form of Patiriella more arched and attaining a larger size than *Patiriella gunnii*; carrying fewer furrow spines on fewer adambulacral plates than *Patiriella gunnii*; subambulacral spines monacanthid.(fig. 7)

Colour.

Consistently rich purple in colour on both surfaces of the body. Tube feet bright orange.

Material examined

Tasmanian Museum Reg. No.	No. of specimens	Locality	Date	Collector
H475	1	Burnie	20. I. 1963	S.A.S.
H457	2	Cape Portland	2.III. 1969	A.J.D.
H474	1	Flinders Is.	8. II. 1969	D.M.
Total	4			

KEY TO THE SPECIES OF *PATIRIELLA* FOUND IN TASMANIA.

(A field key to the more common Asteroidea of Tasmania is included in Appendix 111.)

1. Rays normally five in number 2

   Rays normally more than five 4

2 (1) Large, R > 15mm. Gonoduct directed aborally .... *Patiriella regularis*.

Small, R < 15mm. Gonoduct absent or directed orally..3

3 (2) Gonoduct absent. Viviparous. Coelomic incubation of young. Actinal surface orange yellow.................... ....*Patiriella vivipara*.

Gonoduct directed orally. No internal incubation. Actinal surface blue green ....*Patiriella exigua*.

4 (1) Rays 6; actinal intermediate spines paired 5

Rays 7 - 11, usually 8; actinal intermediate spines single .... *Patiriella calcar*.

5 (4) Flattened; subambulacral spines usually diplacanthid. Colour when alive varied .... *Patiriella gunnii*.

Arched; subambulacral spines usually monocanthid. Colour when alive consistently deep purple ..*Patiriella brevispina*

Fig.8.

The distribution of Patiriella regularis in Tasmania (dark shaded area).

Inset. Stations from which P.regularis has been recorded in S.E.Tasmania.

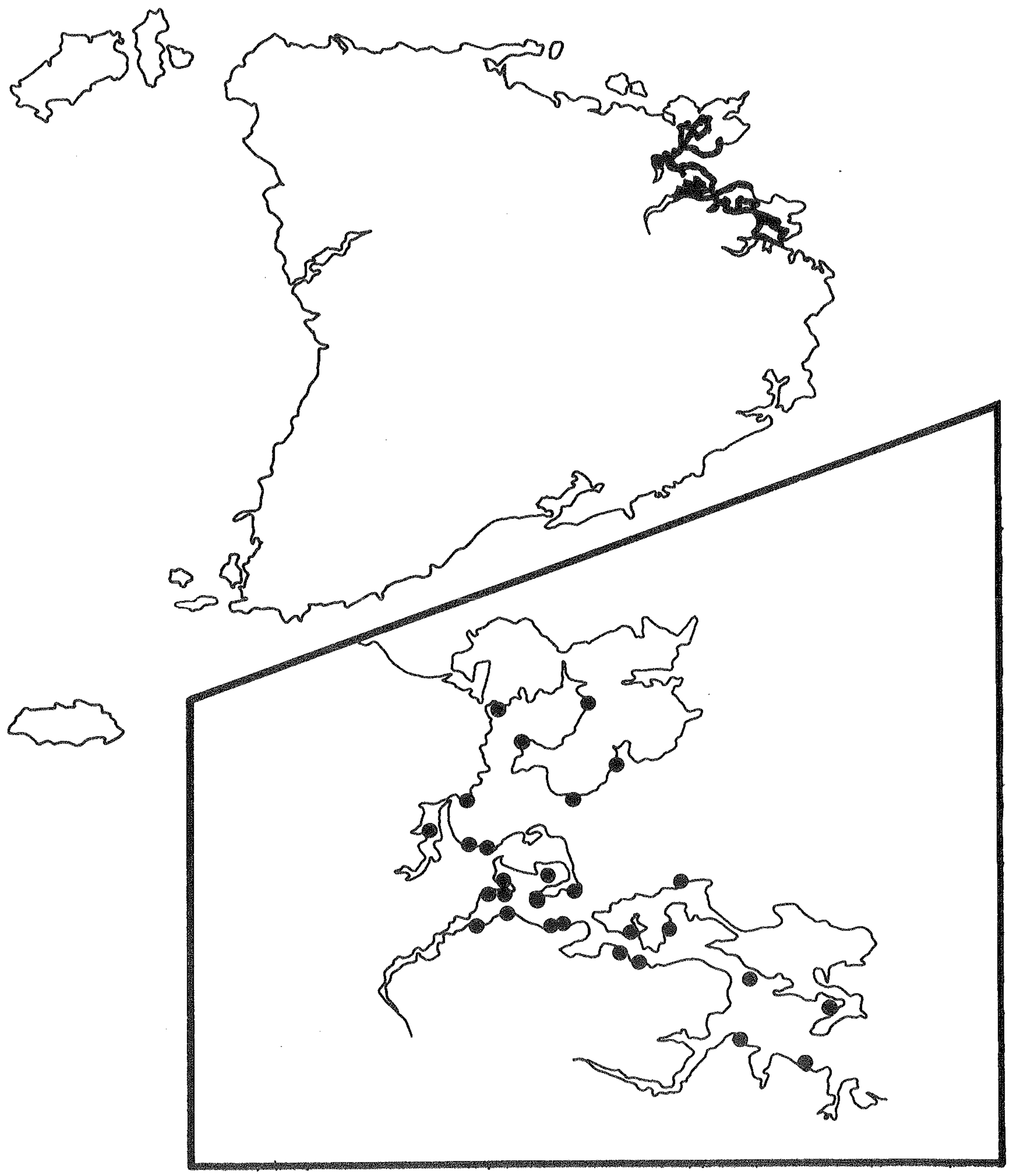


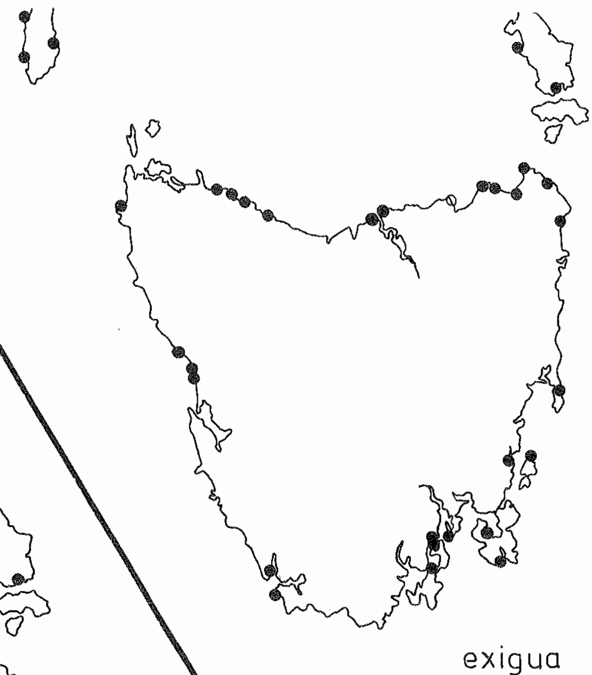
Fig.9.

Stations from which *Patiriella calcar* has been recorded in Tasmania.

Fig.10.

Stations from which *Patiriella exigua* has been recorded in Tasmania.

Fig.10



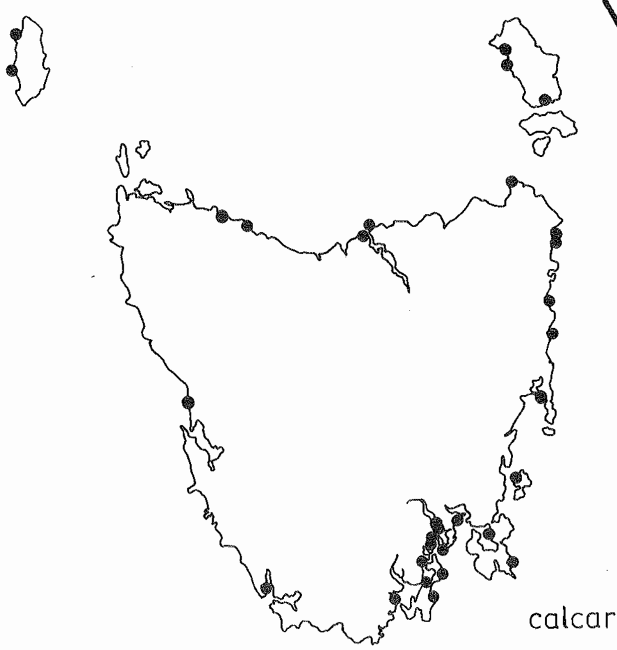


Fig.9

Geographical distribution of the Tasmanian species of *Patiriella*.

1. *Patiriella regularis*.

Now New Zealand and S.E. Tasmania (map fig. 8 and appendix 1 and 1V). Imported from New Zealand. Also one specimen considered this species, by the author, is known from Newcastle Bight, N.S.W., being the holotype and only specimen of *Patiriella mimica* Livingstone, 1933. Examination of the holotype confirms my opinion that *P. mimica* can be relegated to the synonomy of *Patiriella regularis* (see taxonomy of *P. regularis*).

2. *Patiriella calcar*.

Tasmania, Victoria, S.A. to Spencer Gulf, N.S.W., Qld. (map fig. 9).

3. *Patiriella exigua*.

Tasmania, S. and E. Australia (fig.10). Known throughout the Indo Pacific Region (fig. 11).

The type locality is the Cape of Good Hope. By 1876 Perrier was able to record the species from the Red Sea, the Indean Ocean, Java, the Cape of Good Hope and the Island of

Fig.11

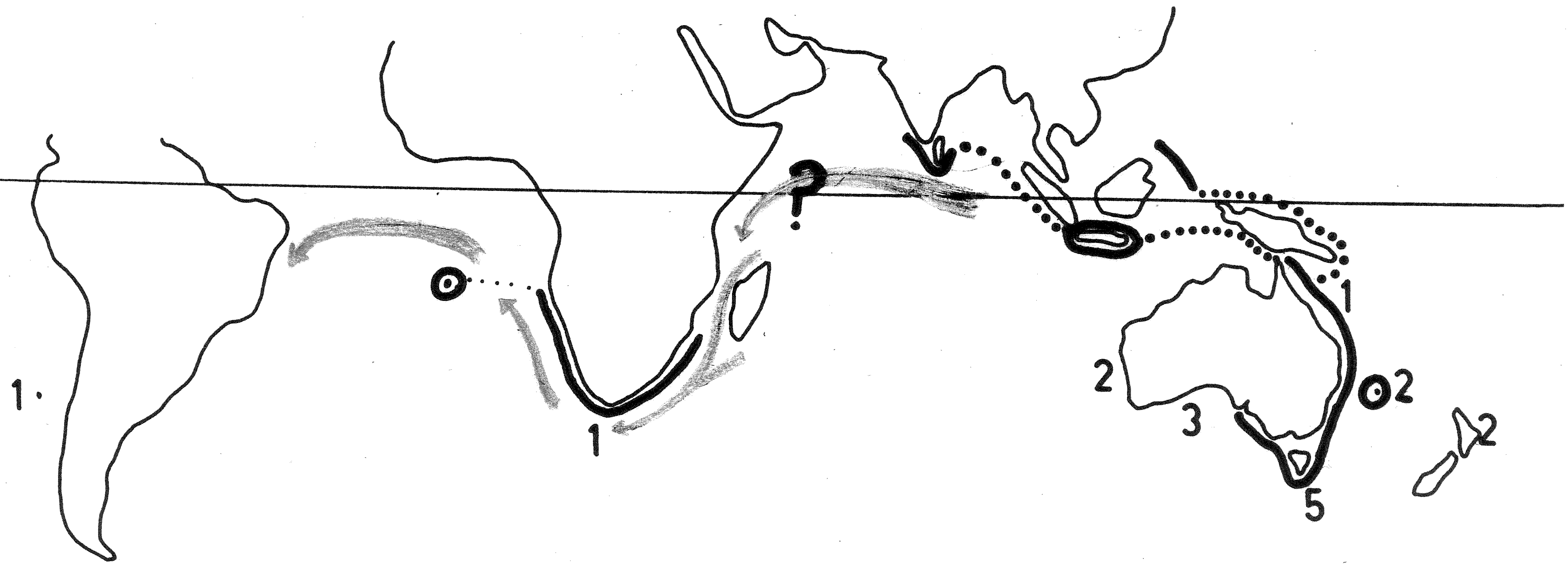
Distribution of Patiriella exigua in the Southern Hemisphere.

Said in the literature to be common in the Indo-Pacific, the records actually available show a distribution following the solid lines of the diagram. Inferred distribution throughout the East Indies is shown by dotted lines. So little information is available between Natal and the N.W.Indian coast that a query is recorded.

Main ocean currents that may be responsible for the spread of the species is shown by grey arrows.

It is postulated that P.exigua may be a poly morphic group of species worthy of further investigation.

Numbers superimposed show the numbers of Patiriella species known from each area. Patiriella calcarata from the Juan Fernandez Islands constitutes the South American representative.


1.
?
1
1
2
3
5
2
2

St. Paul remarking that "il n'y a rein d'etonnant, en conséquence, qu'elle puisse se retrouver jusqu'en Australie."

By 1889 Sladen was able to confirm Perrier's prediction and various workers have added more intimate details to the known distribution of the species. Koehler (1910) recorded *Patiriella exigua* from India, H.L. Clark from Australia (1938, 1946 and previous reports), South Africa (1923), the Torres Straits (1921) and Mortensen (1933 in Fell 1967) recorded the occurrence of the species on St. Helena, washed ashore on fronds of *Ecklonia* carried westward by the Benguela current. One awaits the arrival of *P. exigua* in S. America, continuing its crossing of the South Atlantic by the South Equatorial Current to make landfall by the easternmost extremity of Brazil (Fell 1967).

For a map of the distribution of *P. exigua* see fig 11.

4. *Patiriella vivipara*

Restricted to S.E. Tasmania. One station from which the species was collected appears to exist no longer (Appendix V).

Over three years the species has extended its range in the area around Midway Point. (see fig.12.)

It should also be recorded that the known range of *Patiriella vivipara* coincides in many respects with that of

Fig.12

The distribution of *Patiriella vivipara* in S.E. Tasmania.

Inset. Stations from which the species has been recorded.

Main map. Frederick Henry Bay and Pittwater area showing the distribution of *Patiriella vivipara* and the extensions of local range along the shores of Midway Point, 1967-1969.

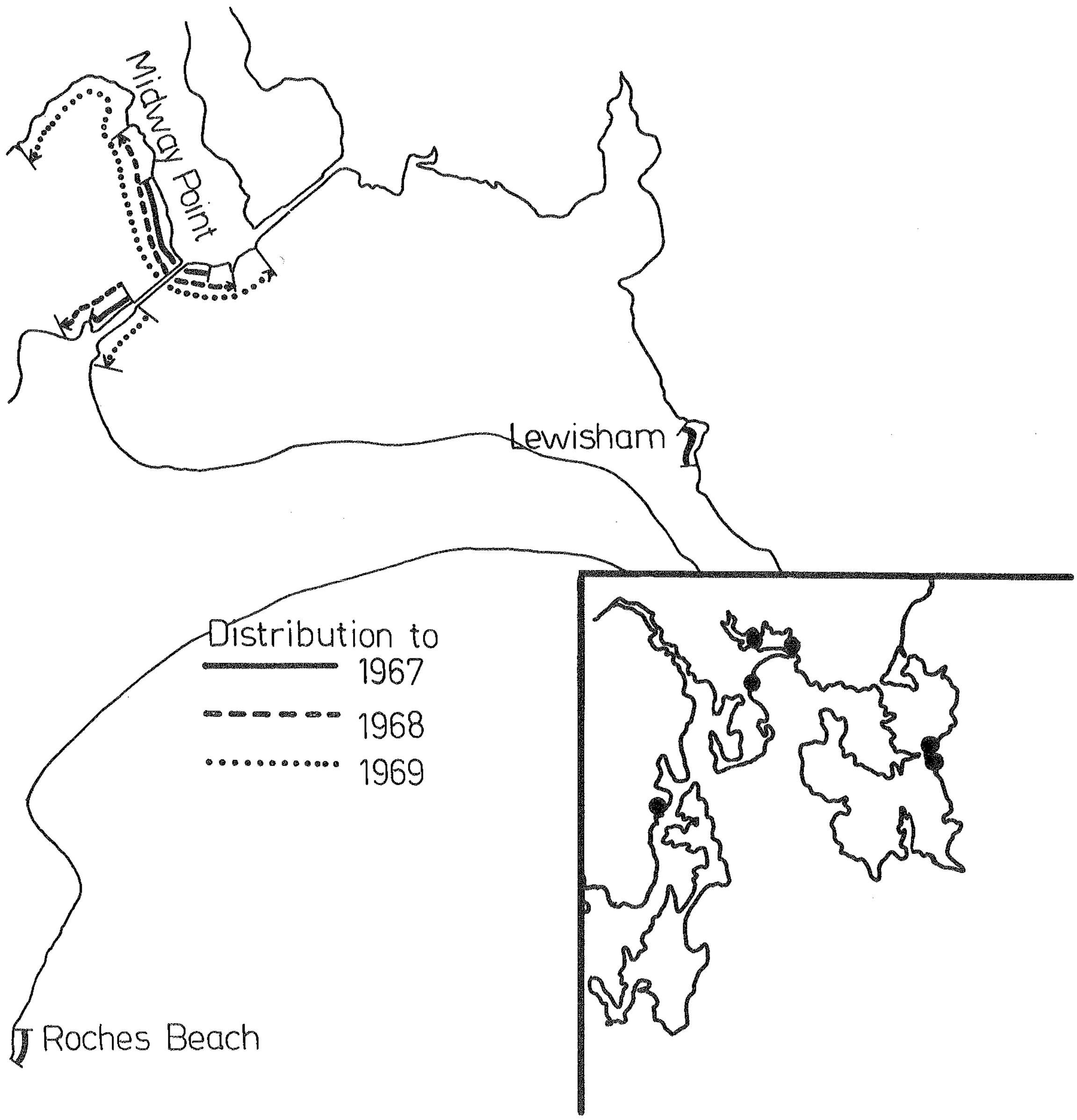
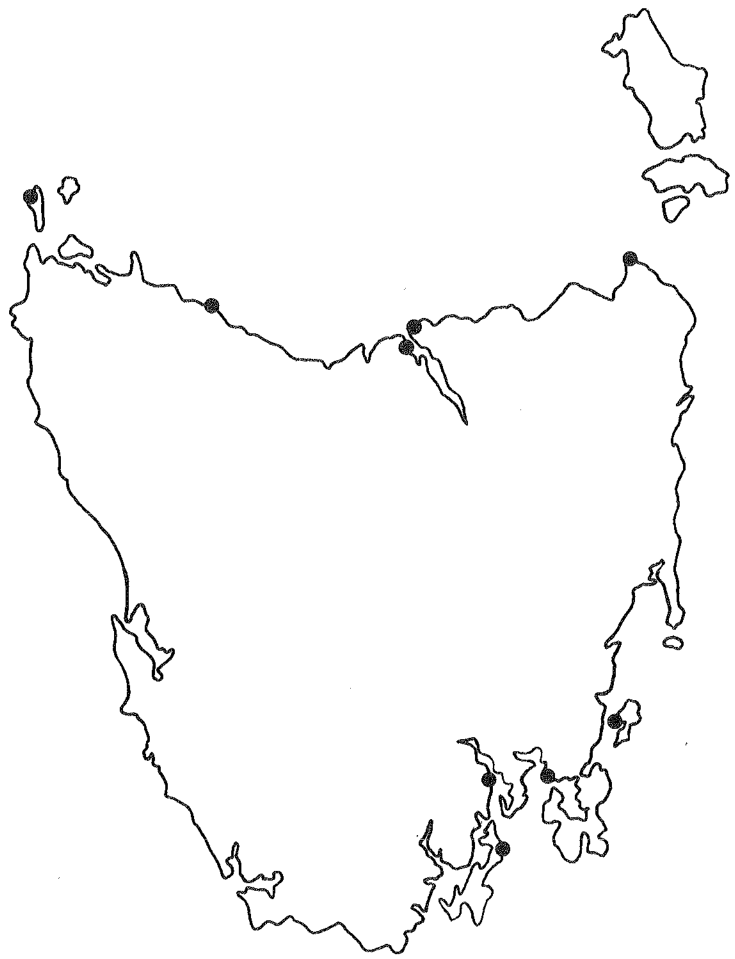

Midway Point
Lewisham
Distribution to
1967
1968
1969
Roches Beach

Fig.13.

Stations from which Patiriella gunnii has been recorded in Tasmania.

Fig.14.

Stations from which Patiriella brevispina has been recorded in Tasmania.



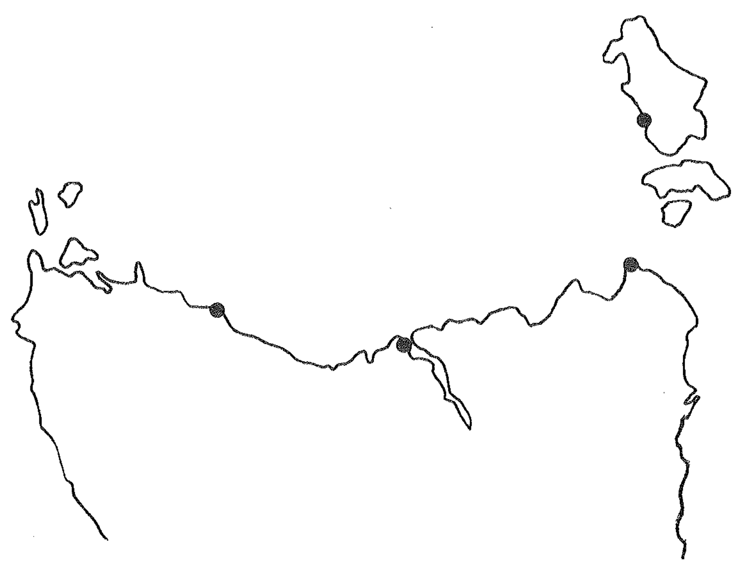


Fig.15.

Distribution of the species of *Patiriella* found in Australia.

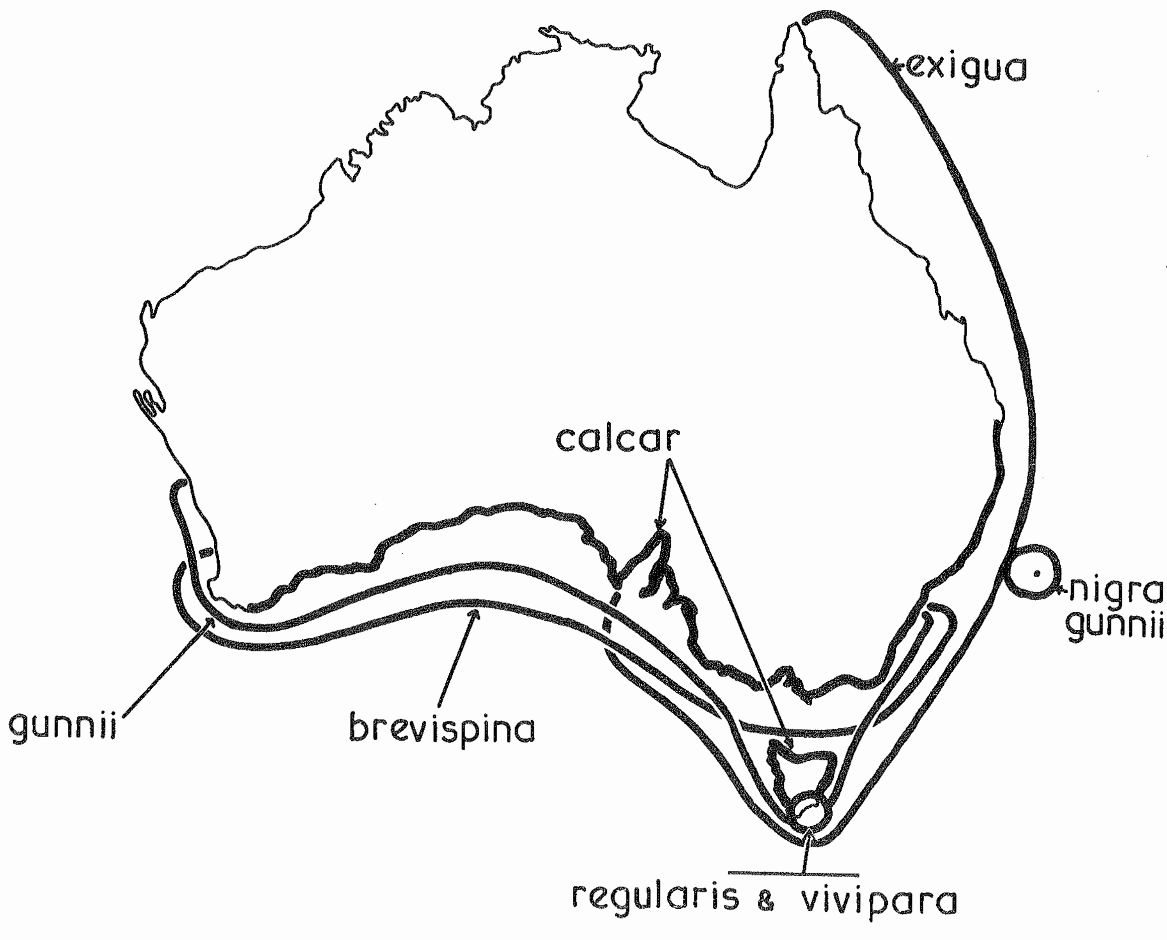
Note a) the restricted distribution of both *Patiriella regularis* and *Patiriella vivipara*.

b) the apparently restricted distribution of *Patiriella nigra* to Lord Howe Island.

c) the very similar distributions of *Patiriella gunnii* and *Patiriella brevispina* with *P.gunnii* extending further south into Tasmanian waters.

d) the Flindersian,Maugean and Peronian distribution of *Patiriella calcar*.

e) the apparent absence of *Patiriella exigua* from the warm temperate Flindersian province.


exigua
calcar
nigra
gunnii
gunnii
brevispina
regularis & vivipara

Patiriella regularis in Tasmania. Evidence has been presented for the import of *P. regularis* into S.E. Tasmania along with other animals of New Zealand origin (Appendix 1 and 1V) and it may yet happen that *Patiriella vivipara* will be found in the vicinity of Bluff, New Zealand.

5. *Patiriella gunnii.*

Tasmania, N.S.W. and Lord Howe Island, Victoria, S.A. and W.A. So far only recorded by this author from the north and east coasts of Tasmania (map fig. 13). Cannot be found in the type locality.

6. *Patiriella brevispina.*

Tasmania, N.S.W., Victoria, S.A. and W.A.

Recorded, so far, only from the north coast of Tasmania.(maps fig. 14)

The distribution of the species of *Patiriella* throuhgout Australia is shown in fig. 15.

Vertical distribution of species of Patiriella.

The method chosen to list and compare the observations of the author is to list the authors observed limits and follow this by the information gleaned from the literature. Upper, mid, lower and sub-littoral zones are considered adequate divisions of the littoral in this case.

For further zonation details see Bennett and Pope (1960).

Table I. Vertical distribution of the Tasmanian species of *Patiriella*.

Species	Upper littoral	Mid littoral	Lower littoral	Sub littoral	Reference
P. regularis		-	-	15 m.	author
			-	30 m.	Fell, 1959 (New Zealand).
P. calcar		-	-	to 10 m.	author
			-	-	A.M. Clark, 1966 (Port Philip).
		?	-	-	Shepherd, 1968 (South Australia).
		-			Bennett and Pope, 1960.
P. exigua	-	-			author
	-	-			Dakin, 1960.

		?			Shepherd, 1968 (refers to "an intertidal habitat).
		-			Bennett and Pope, 1960.
P. vivipara		-			Dartnall, 1969.
P. gunnii		-	-	to 15 m.	author.
				to 30 m.	Shepherd, (1968).
		-			Bennett and Pope, 1960.
P. brevispina		-	-		
				to 10 m.	Shepherd, 1969.
				-	Smith (pers. comm.) (Port Philip)
		?	-		Dakin, 1960.
			-	8 fath.	H.L. Clark, 1938.

COMMENTS ON DISTRIBUTION.

Patiriella regularis.

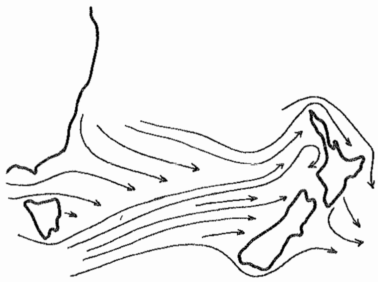
Fell (pers. comm.) has attempted to explain variation within the Cook Strait, New Zealand populations of *P. regularis* by referring such variation to hybrids with *Asterina novaezelandiae* Perrier. The latter species is of doubtful validity and it has been suggested that it is a variant of *P. regularis* or swamped by introgressive variation with that species (Fell, 1959). Fell has also suggested that *Asterina novaezelandiae* may be referred to the genus *Patiria*.

A further suggestion that may apply is that specimens of *P. regularis* have reached New Zealand from Tasmania attached to floating objects. Larval life is certainly too short for planktonic travel over such distances but the current patterns could conceivably carry adults attached to such objects. Dell (1952) analysed Russell's 1894 - 1904 drift bottle experiments and commented that "it is possible .... for drifting masses of algae and associated animals to make the direct journey from the southern tip of South America to southern Australia or New Zealand in less than three years." Speeds of travel indicated ranged from 1.4 - 13.3 miles per day. Wyrtki(1960) considered the surface circulation of the Tasman Sea and his current diagrams from which fig. 16 is constructed show that the surface current patterns are aligned to make transport of drifting objects

Fig. 16.

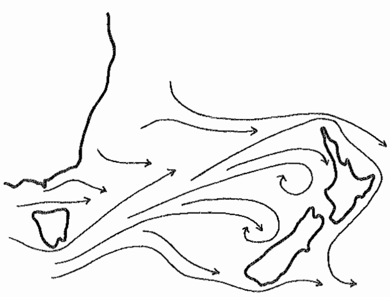
Current patterns of the surface waters of the Tasman Sea for January, March and May and a generalised current pattern throughout the year.

(Modified from Wyrtki, 1960.)

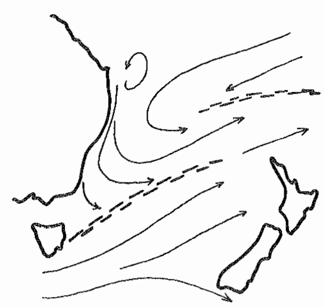


JANUARY

MARCH



MAY



GENERALISED CURRENT PATTERN

to New Zealand from Tasmania a tenable theory. Sutherland, (1965) and Sutherland and Olsen, 1968 considered the distribution and peristence of drift pumice to the south of Australia. Two points of interest in regard to epiplanktonic distribution from Tasmania were raised by these authors.

1) That the south coast of Tasmania is under the influence of the West Wind Drift during both summer and winter thus providing a continual conveyer belt of surface currents towards New Zealand.

2) Speed of travel of pumice was calculated as an average of 18 miles per day - nearly a third faster than the maximum speed calculated by Dell.

Fell (1962 b) demonstrated how the West Wind Drift may have affected the dispersal of echinoderms in the southern hemisphere.

If one assumes that the West Wind Drift and its associated currents can carry floating materials towards the southern tip of New Zealand which from thence are carried northwards towards Cook Strait in the Notonectian Current (see Dell, 1952) then recruitment of biological material from Tasmania is a possible proposition. In such a case the Cook Strait populations of Patiriella regularis could recruit individuals reflecting a restricted amount of variation originally derived from a restricted sample from Bluff - the southern end of the range of the species within New

Zealand.

The evidence for epiplanktonic dispersal of animal species is not very strong except in those cases where landfall of a species has been observed. The circumstantial evidence that such transport may occur and that the mechanisms for its operation are feasible appears to be growing.

Patiriella calcar.

Probably one of the most common littoral sea stars of the southern coasts of Australia (H.L. Clark, 1946). Mentioned by Bennett and Pope (1960) as being "better developed at the warmer ends of the temperate region."

Patiriella exigua.

Said to range throughout the Indo-Pacific; associated with the alga *Hormosira banksii* in Australia and *Ecklonia* (presumably a littoral species) on the African coasts (Mortensen, 1933).

Some difficulty arises when distribution outside Tasmania is considered. The species as known in Australia is restricted to the south and eastern seaboards of the continent. South to north its range extends from Tasmania to Torres Strait. Following Bennett and Pope (1953) this is within a range of minimum water temperatures from 11.7° C to 21.4° C. In shallow pools the species may be taken from water of 30 - 35° C (Shepherd 1968) and death occurrs, in laboratory experiments, within minutes at 50° C, within 24 hours at 40° C.

It is difficult to decide whether those animals known, throughout the Indo Pacific region, as _P. exigua_ are a) the same species, b) the same species with populations of different temperature tolerances or c) a series of very similar sibling forms that possess characteristics that isolate each group effectively enough to support the concept of a series of distinct species.

South African material attributed to _Patiriella exigua_ available to this author certainly contains forms that appear equivalent to Tasmanian material; however, a further proportion of the sample contains forms that are larger than any specimens of _P. exigua_ recorded from Tasmania, which are more stellate in outline. In conclusion it will be argued that the traditional species concept, as applied by echinoderm taxonomists over the last 100 years, is of little use in delineating the critical parameters of the Asterinidae, and the example above is only one anomaly among many.

It may be that specimens of asterinid sea stars found in Australia from Brisbane northwards and throughout the Indo-Pacific that are attributed to *Patiriella exigua* are part of a polymorphic series of asterinids that will repay closer study.

Patiriella vivipara.

Fossil material relating to spinulose asteroids is rare in Australia. It is difficult to decide whether *Patiriella vivipara*, being restricted to S.E. Tasmania is a relict or recent species. No evidence has been discovered to validate the former and on the basis of the close morphological similarity of *P. vivipara* to *Patiriella exigua* it is tentatively offered that *P. vivipara* is of more recent evolution.

Patiriella gunnii and *Patiriella brevispina*.

Both of these species are too imperfectly known to comment upon with significance. *Patiriella brevispina* is said to be an inhabitant of colder waters than *Patiriella gunnii* (Dakin, 1960) which may correspond with Shepherd's (1968) statement 'and in sheltered locations along the open coasts.

Both species have been taken in identical situations on the north coast of Tasmania. *Patiriella brevispina* has not been taken further south than Cape Portland so far whilst *Patiriella gunnii* is known from off Maria Island and as a low littoral species in the S.E. of Tasmania.

It is interesting to note *Patiriella brevispina*'s narrow latitudinal distribution. It is a very distinct form in the field, the colours of the body and tube feet being constant and intense. If the colour of the body is a modified plant cytochrome, as so many asteroid colours are, then it might be thought that specialised feeding would produce the colour. The catholic food list provided by Shepherd (1968) effectively scotches this idea. If one is to accept the theory above for the origin of the colouration observed (no analyses being available) one must fall back on the idea that *P. brevispina* has an inability to excrete pigment precursors from *some* of its food source except by incorporation into the epidermis. Of course, this does not exclude the idea that the red algae upon which the species has been observed to feed are the source of the body colour in life.

MORPHOLOGY.

In the following account, unless stated otherwise, the observations recorded apply to Patiriella regularis.

The body is star shaped consisting of a disc and radially arranged arms. The actinal surface is flat. The body is enclosed in a flexible integument containing numerous calcareous ossides.

The mouth lies at the centre of the actinal surface and is guarded by pairs of oral or jaw plates at the confluence of each ambulacral groove. The ambulacral furrows radiating from the mouth are roofed with interlocking ambulacral ossicles and lined with adambulacral ossicles (fig. 16). The interambulacral areas are paved with a series of characteristically shaped imbricate ossides (fig. 17) arranged in chevrons; showing a lateral assymetry and becoming smaller and more pennate towards the inferomarginal plates which fringe the body. The spinulation of the actinal surface is demonstrated in fig. 18 but it suffices to say here that the plates of the actinal surface carry spines in various combinations. Plates without spines are usually found just back of the mouth plates.

The anus lies near the centre of the abactinal surface surrounded by a ring of spinelets (fig. 19). In one

Fig.17.

Ambulacral ossicle:distal,radial view.

:proximal,radial view.

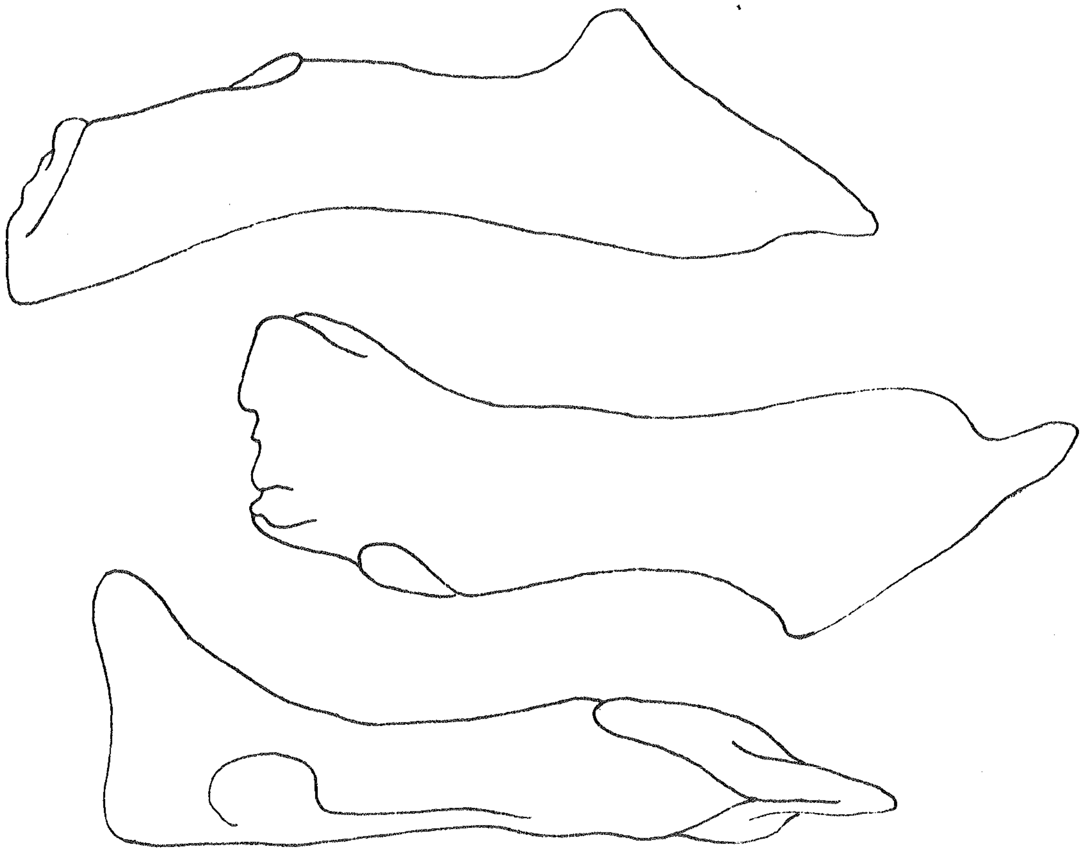
:actinal surface.

Arrangement of ossicles lining the ambulacrum.

a-ambulacral ossicles.

b-adambulacral ossicles.

c-furrow spines.



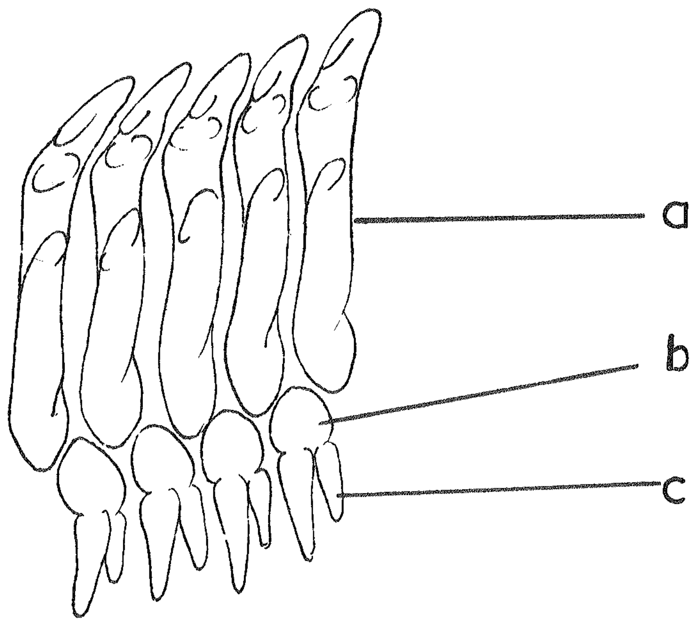
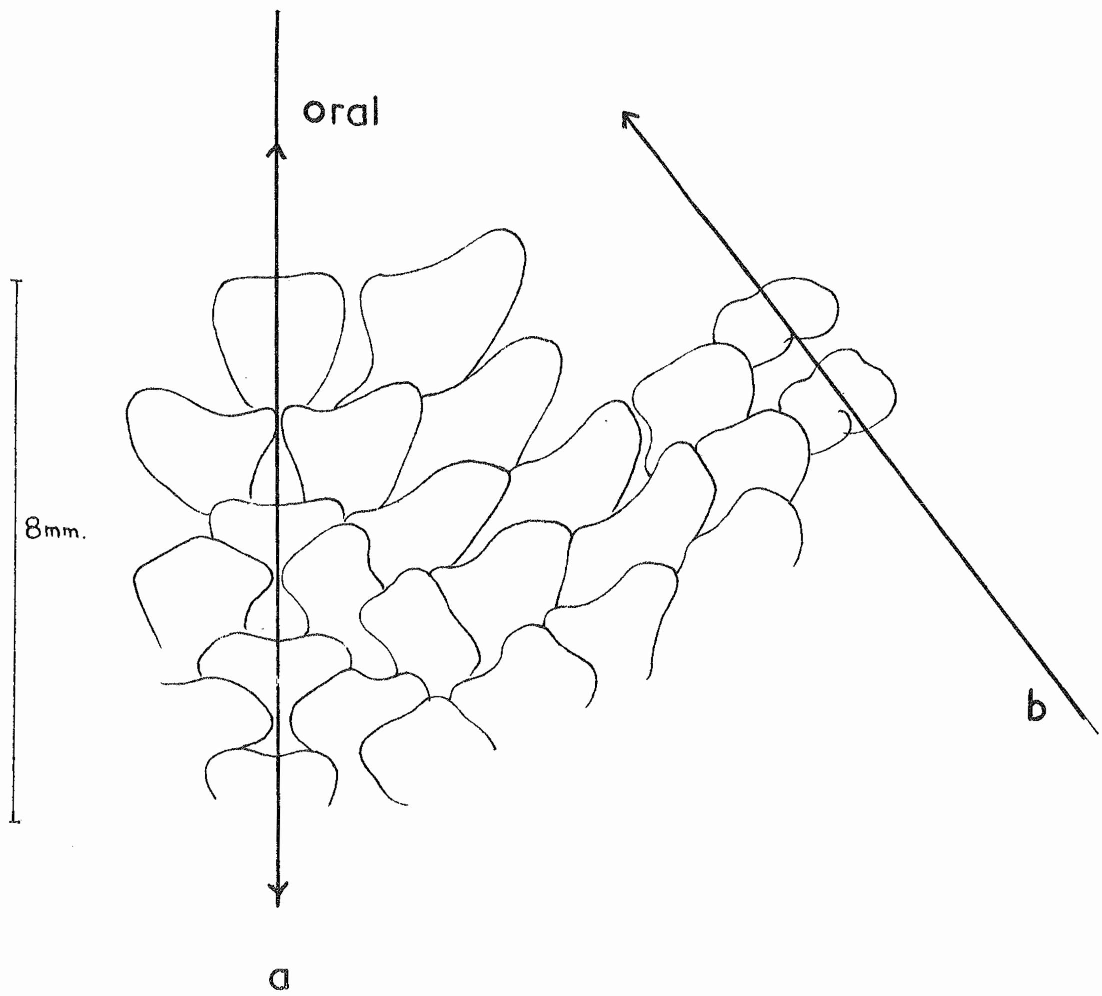

a
b
c

Fig.18.

Interambulacral,actinal plates of P.regularis.

a) Centre line of the interambulacral area.

b) Adambulacral ossicles



oral
8mm.
b
a

Fig.19.

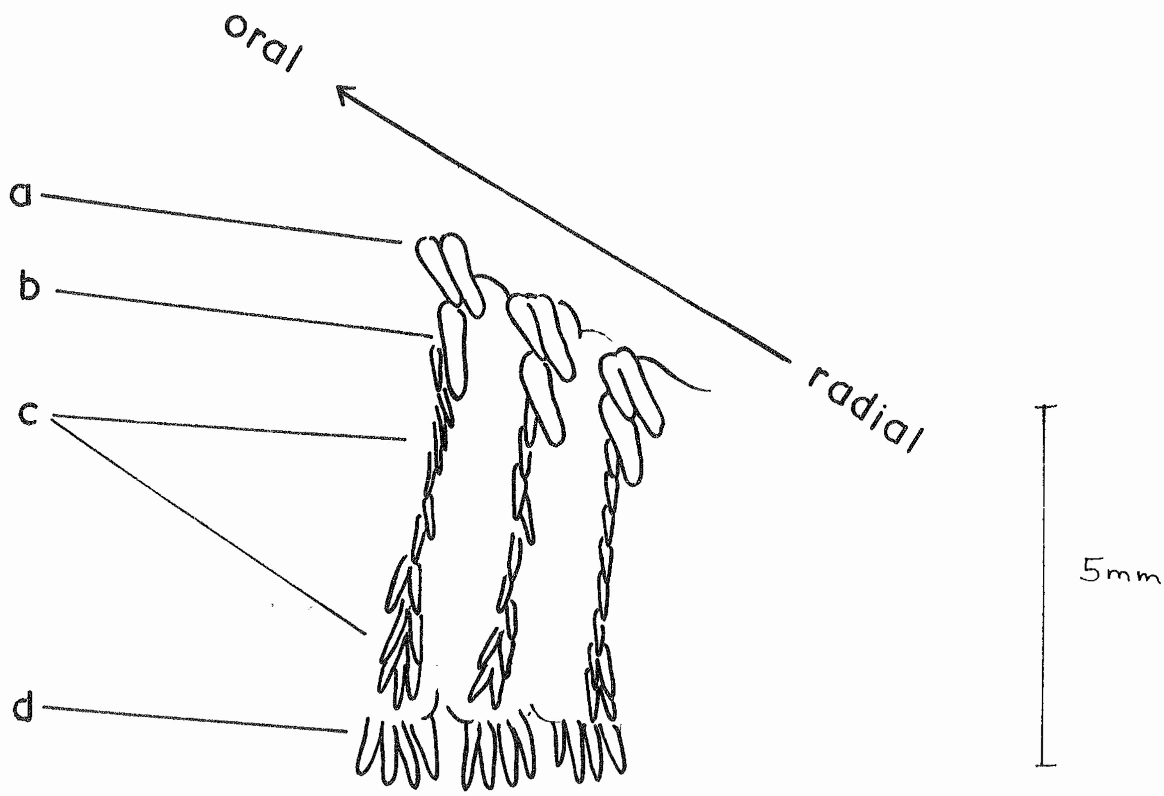
Actinal spinulation of *Patiriella regularis*.

a) Furrow series.

b) Subambulacral series.

c) Actinal intermediate series.

d) Fringing inferomarginal series.



oral
a
b
c
d
radial
5mm

Fig.20

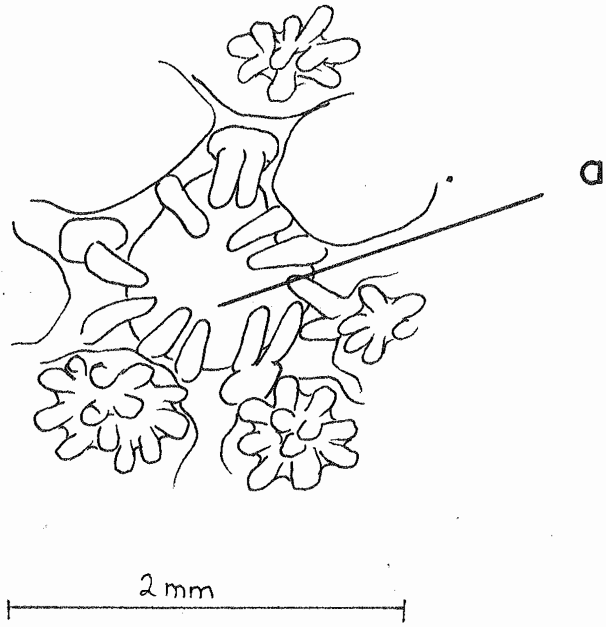
Anus surrounded by spinelets in P.regularis.

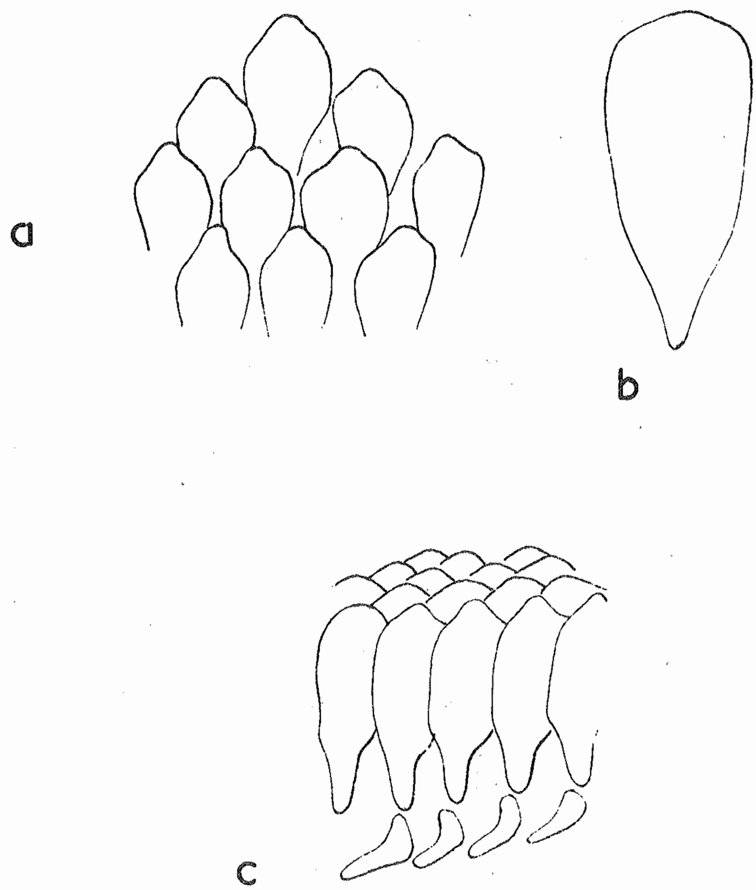
Fig.21.

a) Abactinal,interradial plates.

b) A single,pennate,abactinal,interradial plate.

c) Vertical,radial section to show the arrangement of the actinal and abactinal plates in the distal interradial areas with the bases of the plates approximated to form an arcade of pillars strengthening the edge of the body.


a
2 mm


a
b
c

of the interradii lies the madreporite, rounded in outline, channelled across its surface and perforated with pores in the base of the channels.

The abactinal surface is paved with imbricate plates of two kinds. Those with crescentic depressions to allow the passage of papulae extend from the midline of the ray to the midline of the interradius in a regular succession of interlocking forms i.e. there is an increase in the assymetry from the carinal row of plates towards the interradius. The outer interradial and radial marginal plates are apapulate and pennate (fig. 21), similar to the actinal intermediate plates and extend to the margin where the inferomarginal plates and their spines project beyond the last row (i.e. the superomarginal series) to form the edge of the body. In the fringing areas of disc and ray the "tails" of the pennate abactinal and actinal plates meet forming a strong edge to the body.

Towards the centre of the disc the abactinal plates become larger, more irregular and secondary ossicles are interpolated into the series (fig. 22).

Internally and interradially, at about the level of the most proximal ambulacral ossicles a tripod structure of ossicles (the interbractinal septum) supports the roof of the body, basal insertion of this column being close to the distal end of the mouth plates (fig. 23).

Fig.22.

Patiriella calcar : plates from the centre of the disc showing interpolated secondary ossicles.

Fig.23.

Interradial septum of Patiriella regularis.

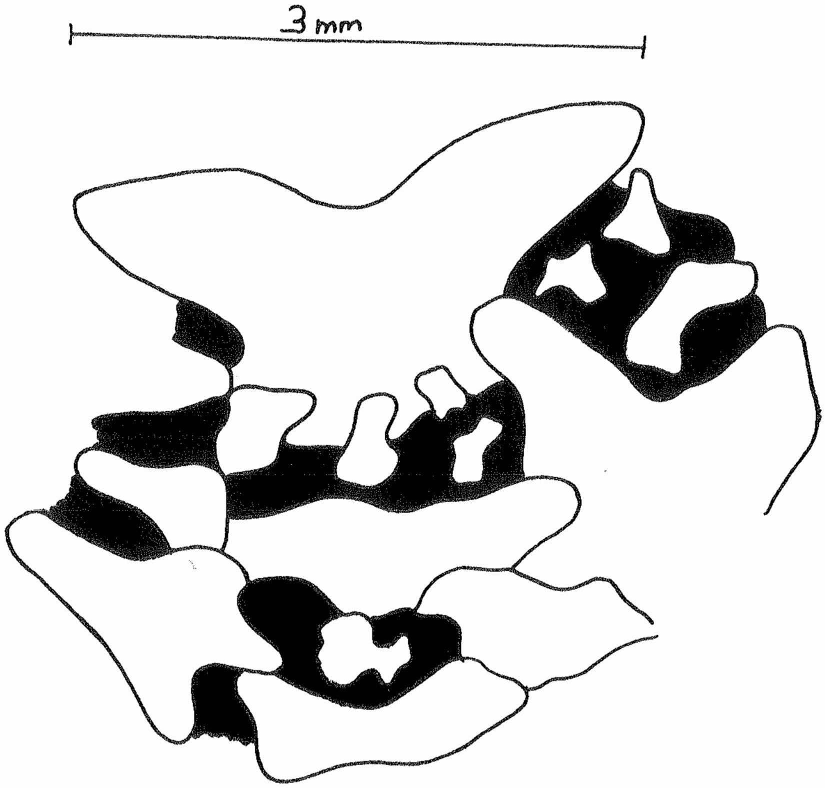
a) Abactinal,interradial plates.

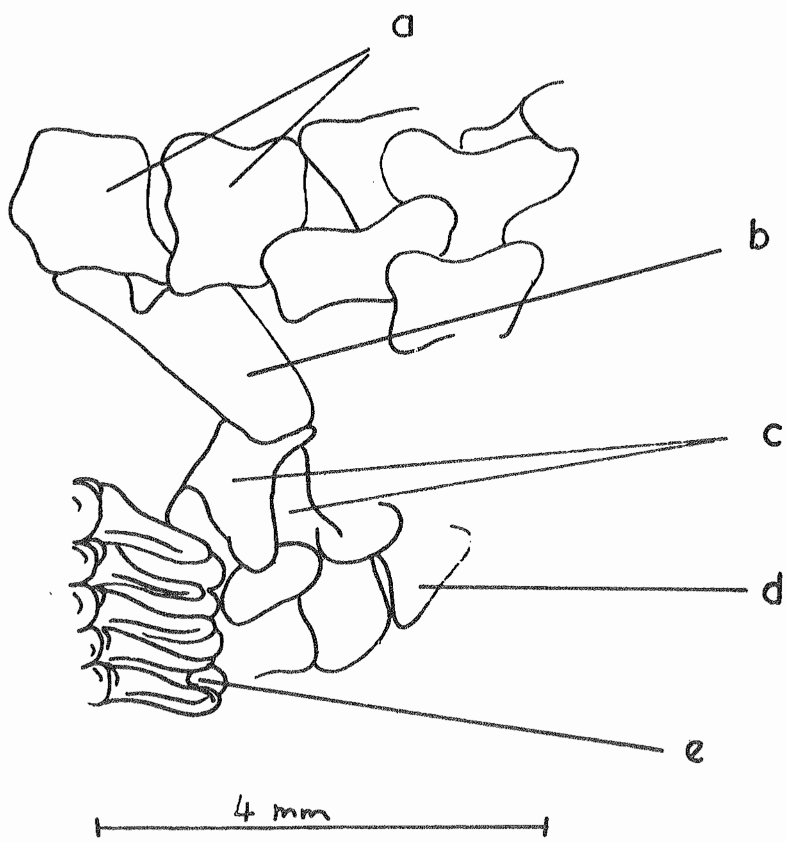
b) Single ossicle of septum tripod.

c) Paired basal ossicles of septum.

d) Interradial actinal plates.

e) Adambulacral ossicles.


3 mm


a
b
c
d
e
4 mm

Two rows of tube feet lie in each ambulacral furrow.

The mouth leads by a short oesophagus into the cardiac portion of the stomach which is broadly five lobed in P. regularis (multilobed in species with more rays) each lobe lying opposite one of the rays. The walls of the cardiac stomach are folded and can be extruded through the mouth to envelope food material or, especially in the case of smaller species, extended across the substrate, even to the limits of the rays, to collect algae and small animals by ciliary action.

The cardiac stomach is retracted by a harness of retractor muscles.(Terminology here follows Anderson, 1959). An extrinsic series of muscles extend from the ambulacral ossicles to the stomach; an intrinsic series spread in a branching pattern over the stomach wall. A constriction marked by a shining band of connective tissue fibres separates the cardiac stomach from the upper, pyloric portion which gives rise to the short intestine which in turn opens at the anus.

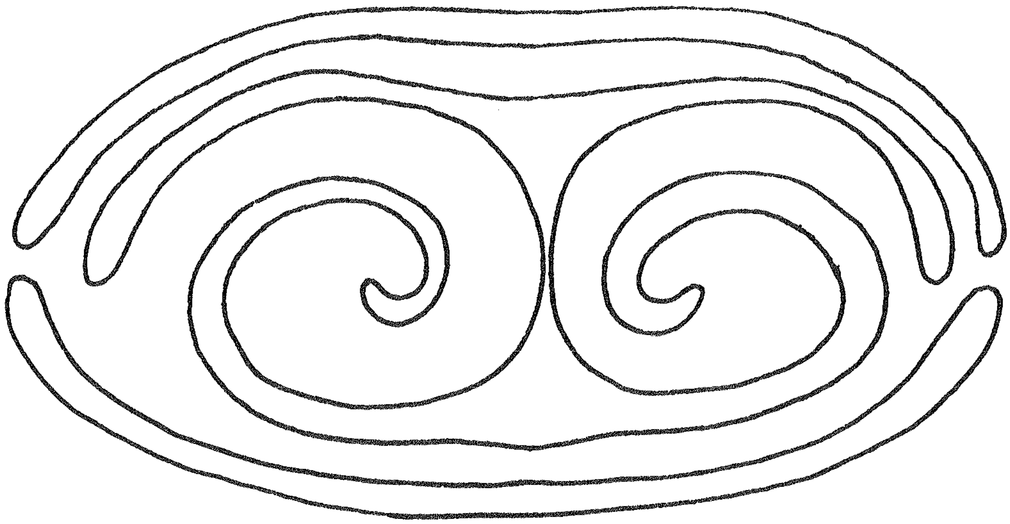
The pyloric portion of the stomach gives off pairs of pyloric caecae which lie in each ray. The pyloric caeca are glandular and act as digestive glands. A conspicuous Tiedeman's pouch is visible along the lower surface of each caecum.

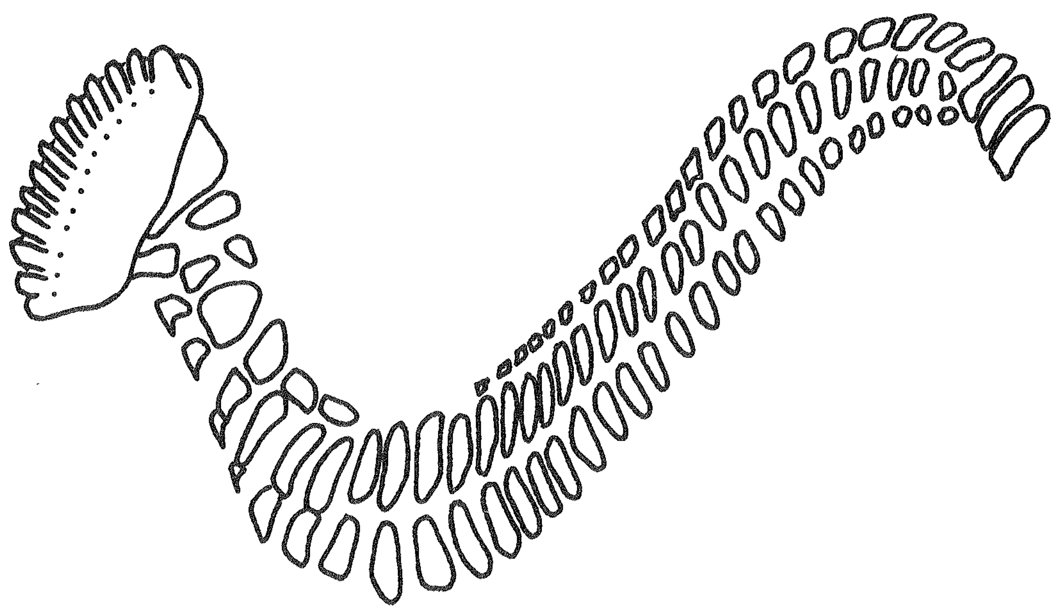
The intestine also gives rise to five pairs of intestinal caecae.

Fig.24.

Diagrammatic transverse section showing the scroll arrangement of the rings of the stone canal.

Ossicles of the stone canal and madreporic plate.





The stone canal runs downward from the madreporite. The walls of the stone are supported by calcareous rings (fig. 24). The stone canal forms the ring vessel of the water vascular system which vessel gives off an ambulacral water vessel which runs along the inner surface of the ambulacral ossicles in each ray. Each ambulacral water vessel gives off ampullae which connect with the tube feet. In each interradius except the one containing a madreporite a Polian vesicle arises from the ring vessel and a pair of Tiedeman's bodies arise from the neck of each Polian vesicle.

The water vascular system components possess a lining epithelium and a muscle layer, the latter being well developed in the ampullae and tube feet.

The stone canal is accompanied by a parallel axial gland which is surrounded by a blood sinus. The sinus in turn connects with the oral ring vessel of the blood system which in its turn gives rise to five radial blood vessels.

The sexes in this species are separate. The gonads are paired masses of follicles in each interradius (fig. 25).

Fig. 25.

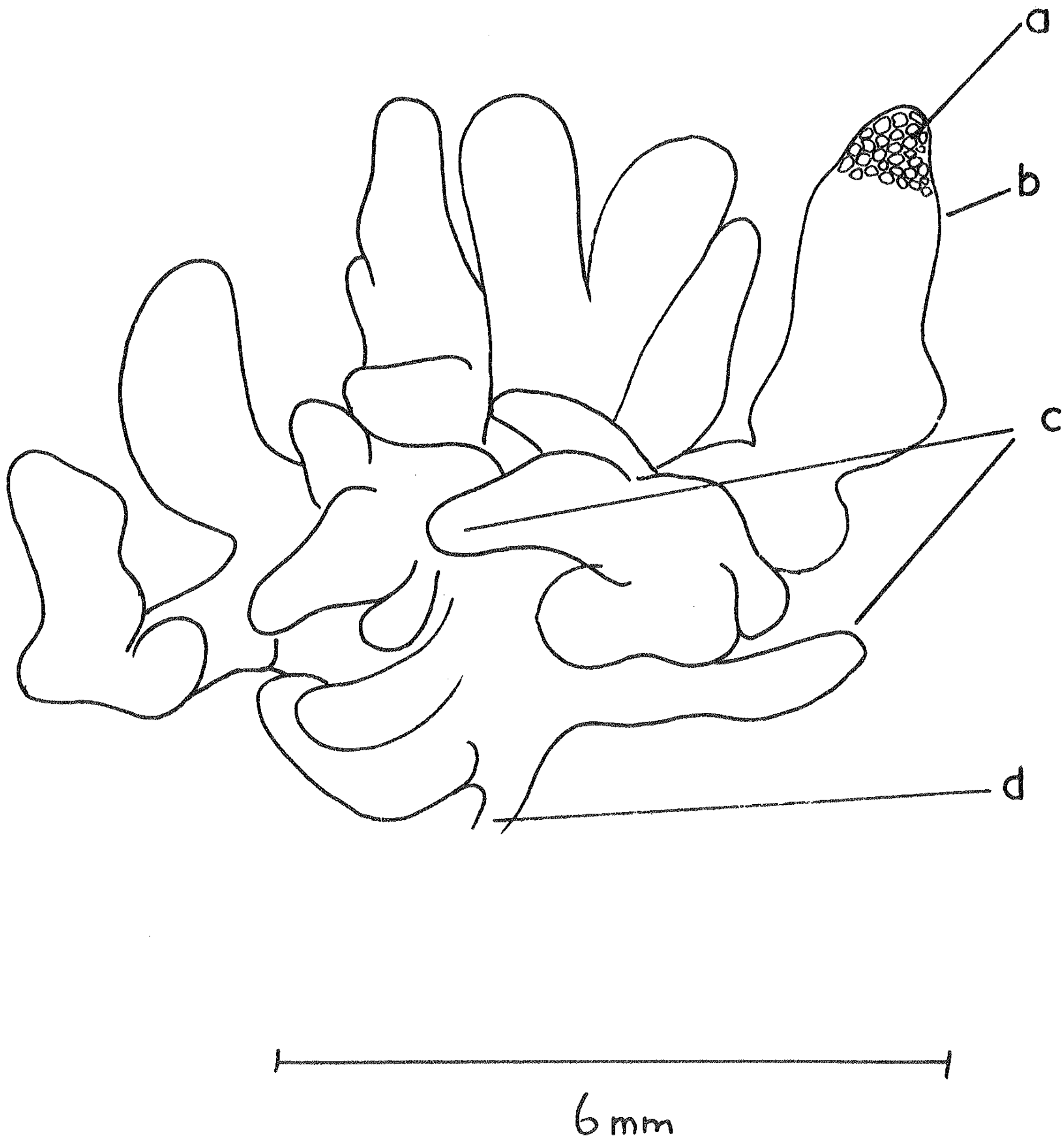
Diagrammatic representation of the gonads of *Patiriella regularis* (female).

a) Packed oocytes.

b) Bounding epithelium.

c) Evaginations of gonad.

d) Gonoduct.


a
b
c
d
6 mm

FOOD AND FEEDING.

Food and feeding in the Asteroidea have recently been reviewed by Feder and Christensen (in Boolootian, 1966). They concluded that the majority of sea stars which have been studied are carnivores which occasionally act as scavengers. These authors review ciliary feeding, partial ciliary feeding and extra- and intraoral digestion in some detail. It is perhaps apposite to point out that the "force theory" for the opening of bivalve prey does not apply in the genus *Patiriella*. At no time has any individual, of the six Tasmanian species, been observed feeding by pulling apart the valves of bivalve molluscs.

Food.

Patiriella regularis.

This species feeds on mussels and small gastropods; on dead *Allostichaster insignis*, *A. polyplax* and *Coscinasterias calamaria* (Bennett, 1927, New Zealand).

Predation of the barnacle *Elminius modestus* in New Zealand by *Patiriella regularis* was inferred by Morton and Miller (1968).

In Tasmania _P. regularis_ has been found feeding on detritus, green and red algae, small mussels and other bivalves (including Kellia sp.), small gastropods (viz. _Notocochlis stricta_) and _Pleurobranchus_ sp. Under aquarium conditions _P. regularis_ appears to feed on almost anything offered from moribund fish to other sea stars.

In the dock areas of Hobart anything of protein origin appears to be taken culminating, for the writer, in the sight of one individual whose cardiac stomach enclosed a number of chicken bones. The species can best be described as an omniverous scavenger and predator of any animal that can be captured and immobilised. This form may also use its cardiac stomach as a ciliary mucous feeding organ.

Patiriella calcar.

Omniverous; detritus, algae (particularly _Laurencia_ sp. and Gelidium sp.), gastropods, pelycopods; also scavenges moribund animals (Shepherd, 1968, South Australia).

In Tasmania observed feeding on or over brown or coralline algae, and on small gastropod and bivalve molluscs and crustaceans. Individuals are often found with the cardiac stomach full of sand suggesting that the animal may be a partial substrate grazer ingesting sand with its included foramnifera, small molluscs and annelids.

Patiriella exigua and *Patiriella vivipara*.

It is suggested that these two species are grazers of algal surface films.

Patiriella gunnii.

Feeding habits similar to *Paranepanthia grandis* i.e. feeding on small gastropods and encrusting compound ascidians (Shepherd, 1968).

Very little information is available from the limited Tasmanian material. One specimen has small particles of brown algae in the cardiac stomach folds but none of the other specimens were recorded feeding.

Patiriella brevispina.

Shepherd (1968) has recorded this species feeding on red algae (*Laurencia* sp. and *Spyridium* sp.), pelycopods, gastropods, decaying animals and bottom detritus. No Tasmanian specimens have been taken when feeding.

Feeding.

The absence of easily recorded food remains in the cardiac stomachs of *Patiriella exigua* and *Patiriella vivipara* and the observation that, in apuaria these species spend much time with the cardiac stomach extruded flat against the glass initiated some investigations into feeding mechanisms.

Anderson (1959) working with *Patiria miniata* Brandt (*Patiria* appears to be the northern hemisphere sister genus to *Patiriella*) demonstrated normal feeding behaviour of that species included frequent and extensive eversion of the cardiac stomach. As a corollary the stomach was provided with a very extensive harness of retractor muscles, prominent Tiedemann's pouches and enlarged rectal caecae. Anderson suggested that the everted stomach could be used as a ciliary mucous feeding mechanism.

Morton and Miller (1968) say "*A. regularis* is not only a carnivore but can graze over algal film extruding part of the stomach to engulf the food."

Observations were confined in this instance to *Patiriella vivipara*. Material was easily available, the species is easily maintained in Petri dishes in the laboratory and facilities were not available to allow the other species to be kept efficiently. Therefore comparative data is provided from dissection of preserved material for the other species. Some general points apply to all. The pattern of the retractor harness is similar in all species most differences being due to size. All the species possess distinct Tiedeman's pouches though both these pouches and the rectal caecae are more prominent among the smaller species.

Feeding mechanisms in *Patiriella vivipara*.

Patiriella vivipara has never been observed, by this author, to envelope and digest small molluscs or similar food. In aquaria they ignore *Kellia* sp. when presented with that bivalve as food, Raw fish and mussel flesh is ignored until decay is evident.

In aquaria and on the shore the everted stomach of this species may extend to the tips of the rays and the animal may remain in this position for 24-36 hours. One individual was not seen to retract the cardiac stomach during the 10 days of observation. Even when the animal was observed moving the stomach remained everted, the animal moving with only two or three pairs of tube feet exposed at the end of the ray.

Both the actinal surface and the everted stomach appear to carry particles towards the mouth. Carbon particles introduced at the edge of the disc will move towards the mouth though not along definite tracks as observed in the Tasmanian species of *Marginaster*. The latter possesses grooves in the epithelium of the actinal surface which extend around the edge of the animal and continue on the abactinal surface for a short distance.

When particles moving towards the mouth over the everted surface of the cardiac stomach are observed closely it is seen that they do not move in the gutters but along the edges of the gutters. The gutters may function to carry digestive enzymes from the intestinal caecae to the substrate.

The cardiac stomach.

When extruded the cardiac stomach of *Patiriella vivipara* can extend to or slightly beyond the borders of the animal. When retracted the cardiac stomach takes up a large part of the body cavity. The pyloric stomach is separated from the cardiac stomach by a band of glistening connective tissue fibres similar to that described from *Patiria miniata* (Anderson, 1959).

Time has not allowed a detailed investigation of the histology and structure of the digestive system as was hoped when the original plan of research was constructed. However certain generalisations can be made.

A complex retractor harness of muscles is present connected between the ambulacral ossicles and the wall of the cardiac stomach. At the stomach wall the muscles can be seen to branch and extend around the stomach. These "extrinsic" elements of the retractor harness consist of fan shaped bundles of muscle and connective tissue. The shortest band originates on the side of the first ambulacral ossicle and inserts on the connective tissue band separating the cardiac and pyloric stomachs. The longest retractor band originates close to the seventh or eighth ambulacral ossicle and also inserts on the band separating the two stomach cavities. The intermediate bands originate from intermediate positions along the ambulacrone and insert onto the wall of the cardiac stomach from whence they branch widely over the surface of the cardiac stomach.

As in *Patiria* when studied by Anderson the stomach, in *Patiriella vivipara*, lacks the nodules on which the harness muscle strands insert which have been observed in species of *Asterias*.

The wall of the cardiac stomach is conspicuously marked with regular, branching grooves or gutters (fig.26). The gutters are conspicuous in the everted cardiac stomach and may be maintained, partially at least, by muscle insertion.

The general histology of the stomach is similar to that described by many authors (see Hyman, 1955 and Anderson in Boolootian, 1966).

The outer surface of the stomach wall consists of flagellated cuboidal epithelium. Two layers of muscle fibres follow in traditional accounts. In *Patiriella vivipara* as in *Patiria miniata* an irregular meshwork of muscle fibres is present obscuring any differentiation

Fig. 26.

Cardiac stomach of Patiriella vivipara.

A— Gutter in stomach wall

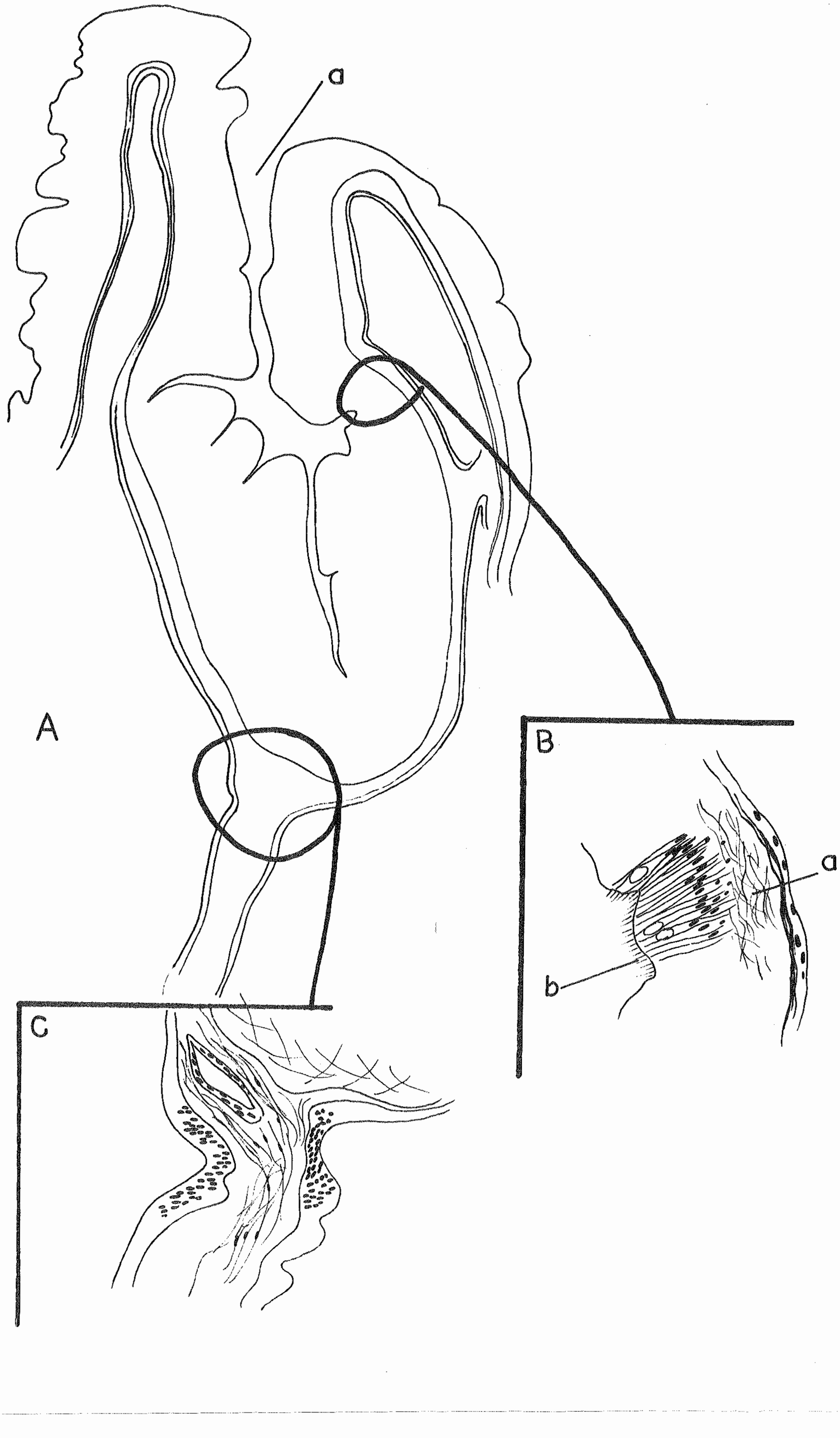
a) lumen of stomach.

B— Section of wall of gutter.

a) muscle and connective tissue.

b) brush border.

C— Site of insertion of muscle strand to the base of the gutter in the stomach wall.



a
A
B
a
b
C

into two layers. It is thus difficult to define circular and longitudinal muscle strands. A layer of connective-tissue is present inside the muscle layers. Where the cardiac stomach gutters are deepest the connective-tissue layer is thicker. This is probably related to maintenance of the form of the gutter and recruitment of strands of connective tissue from the retractor harness. Following the scheme of Anderson (1959), these strands of connective tissue would be called Class 1 strands but, so far, I am unable to classify connective tissue structures observed with such certainty.

The connective tissue layer also acts as a basement membrane for the tall columnar epithelial cells which constitute the main layer of the stomach wall. In many places the epithelial cells join together in bundles before inserting on the basement membrane. The "arcade" effect was noted in _Patiria miniata_ by Anderson.

The tall columnar cells of the epithelium of the stomach possess a brush border at the distal end. Mucous goblets are placed among the epithelial cells, with nuclei usually lying in the basal portion of the cell.

The floors of the cardiac stomach gutters are lined by comparatively low columnar cells. The side walls of the gutters comprise very tall crowded cells. Where the walls rise from the floor a narrow zone of transition is visible between the two kinds of epithelia. Whether this be a true observation or a mechanical artefact is not known.

Digestion of food materials drawn into the cardiac stomach is rapid. In *Patiria*, suggested Anderson, digestive enzymes are produced in the pyloric caeca and not from the cardiac stomach. As particles have not been observed to move towards the mouth in the gutters of the everted cardiac stomach it was decided to repeat Anderson's experiment with *Patiriella vivipara*. Seven mature specimens of *P. vivipara* were operated upon to remove the pyloric caecae. With such small specimens key-hole surgery was necessary and only two specimens survived longer than 14 days. After 18 days the two remaining specimens were seen to evert the cardiac stomach normally. At 21 days the stomachs were removed and the contents examined. No digestion appeared to have taken place on the algae and debris extracted looked similar to a sample scraped from the aquarium wall.

REPRODUCTION.

REVIEW.

Hyman (1955), Feder and Christensen, Boolootian and Delavault (all in Boolootian, 1966) have all reviewed aspects of echinoderm reproduction.

As a rule sea stars are gonochoric and among a limited number of species hermaphrodite specimens may occur (Hyman, 1955). *Fromia ghardaqana* appears to be a true protandric hermaphrodite (Mortensen, 1938) and *Asterina gibbosa* a protandric hermaphrodite at the north of its range (Cuénot, 1887). Bacci (1949, 1951) extended Cuénot's further discovery (1898) that *A. gibbosa* is sexually polymorphic by elucidating "balanced" and "unbalanced" hermaphrodites. The balanced forms changed sex at a specific time during the life span; the unbalanced forms changed earlier or later or could remain male or female. Further comment was provided by Oshima (1929) who demonstrated unbalanced hermaphrodism in *Asterina batheri* from Japan.

Detailed histological studies of the gonadial tissues of *Asterina gibbosa* coupled with research into determination of sex in that species were reported by

Cognetti and Delavault in numerous papers (for full references see Delavault in Boolootian, 1966).

Feder and Christensen classified the Asteroidea according to their mode of development and reproduction following Thorson (1936, 1946 and 1950).

Thus:-

1. Species which shed their sexual products freely in the water and have small eggs and pelagic planktotrophic larvae. The majority of littoral and shallow water asteroids belong to this group.

2. Species which shed their sexual products as group 1, but possessing larger eggs and planktonic, leanthropic larvae. Crossaster papposus and Solaster endeca are examples of this group.

3. Species with large eggs and direct development. This is probably the dominant type of reproduction among deep sea Asteroidea.

4. Species with large eggs, direct development and brood protection. This is an important mode of development amongst Antarctic and Subantarctic asteroids. Thorson(1950) estimated that 44% of the species then known from those areas protect their brood.

5. Asexual reproduction by fission has recently been reviewed by A.M. Clark (1967) and two points emerge :-

a) That although fissiparity is common no suppression of sexual reproduction has been observed.

b) Although *Asterina anomala* H.L. Clark, *Asterina burtoni* Gray and *Asterina heteractis* H.L.C. are recorded as fissiparous by Miss Clark no reference is made to the genus *Patiriella* although *Patiriella exigua* is said to be fissiparous (Bennett, 1927). This author has seen no evidence of fissiparity in that species from Tasmania.

REPRODUCTION IN *PATIRIELLA VIVIPARA*.

The discovery that *Patiriella vivipara* is hermaphrodite and demonstrates internal, abbreviated development was reported briefly elsewhere (Dartnall, 1969. See Appendix V).

Initially the animal was observed to carry developing young in the interradii (see fig. 27 and fig. XXIX of Appendix V). The animal has been observed to breed throughout the year and the gonad tissue is hermaphrodite. The young develop in sacs derived from the gonads and when 1 - 2 mm R is attained they rupture the incubatory sac, enter the coelom and emerge between the abactinal plates of the adult.

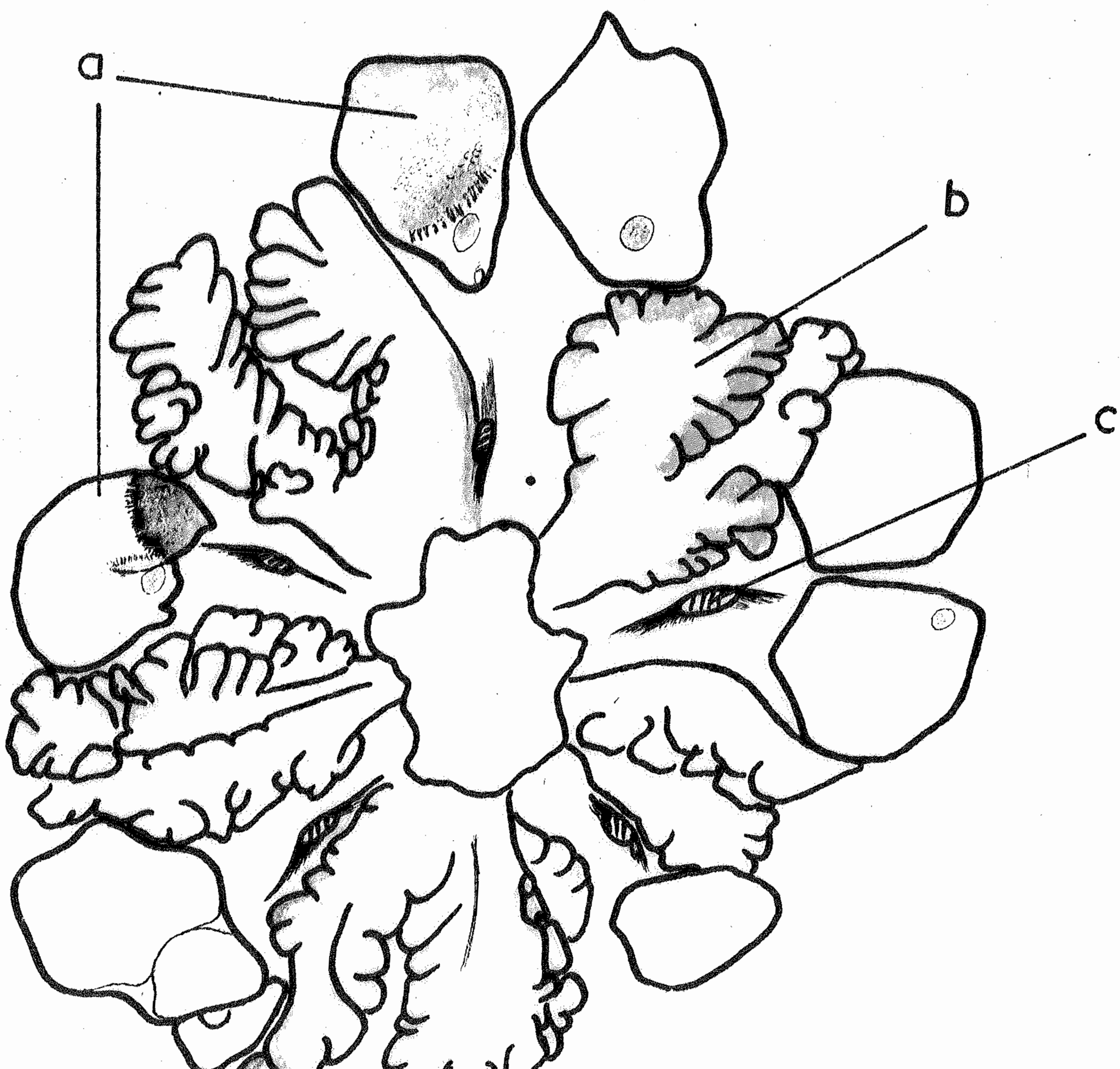
Fig.27.

Drawing to show developing young in the gonads of Patiriella vivipara. Abactinal surface of adult removed.

a) Gonads with young stars.

b) Pyloric caecae.

c) Interbrachial septum.



a
b
c

Fig.28.

Patiriella vivipara : horizontal section showing location of gonads.

a) Gonad with male tissue only.

b) Gonad with young star.

c) Oocytes around edge of lumen of gonad.

d) Adambulacral ossicle.

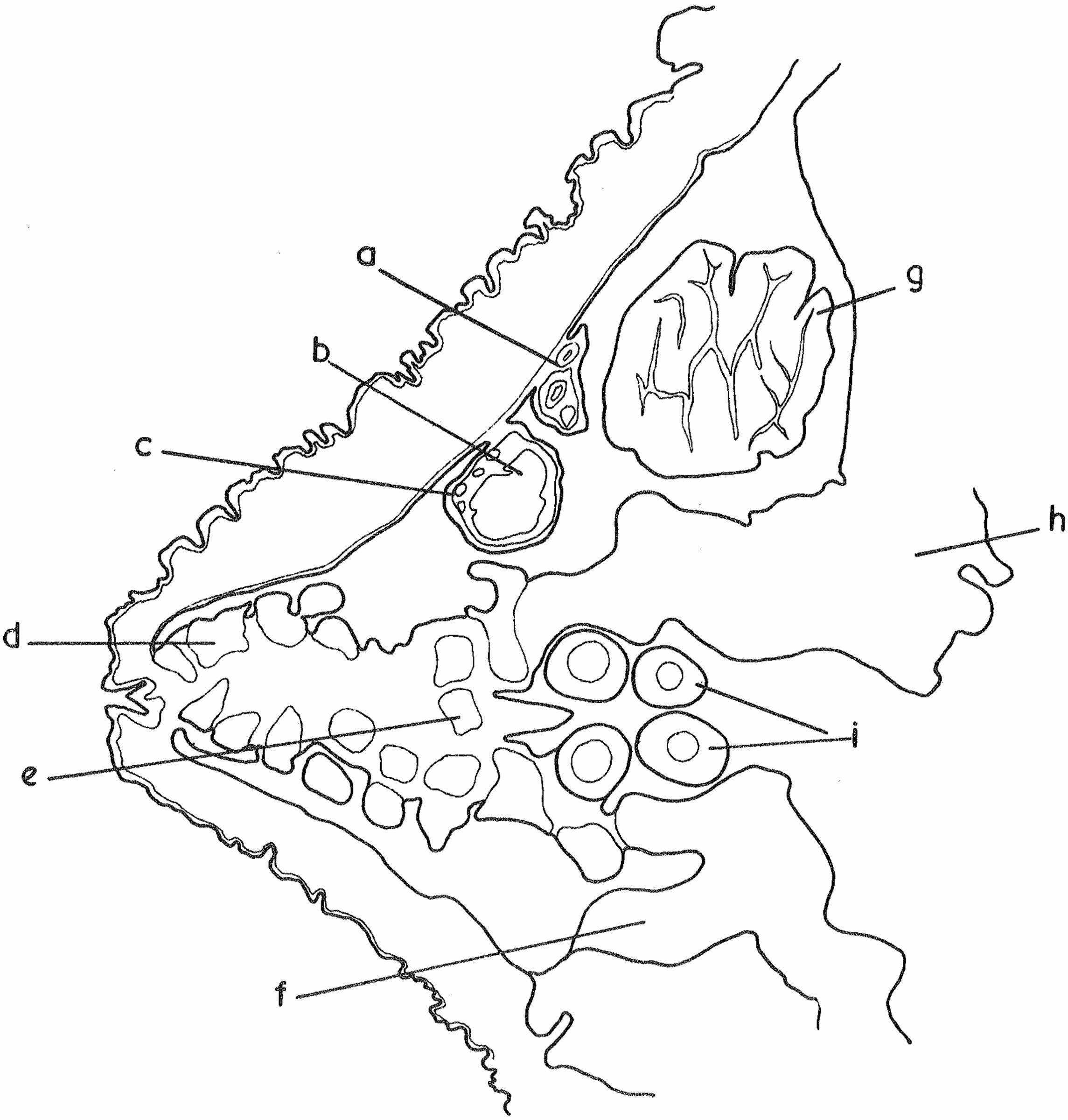
e) Ambulacral ossicle.

f) Interbrachial septum.

g) Portion of pyloric caecum.

h) Oral plates.

i) Tube feet.



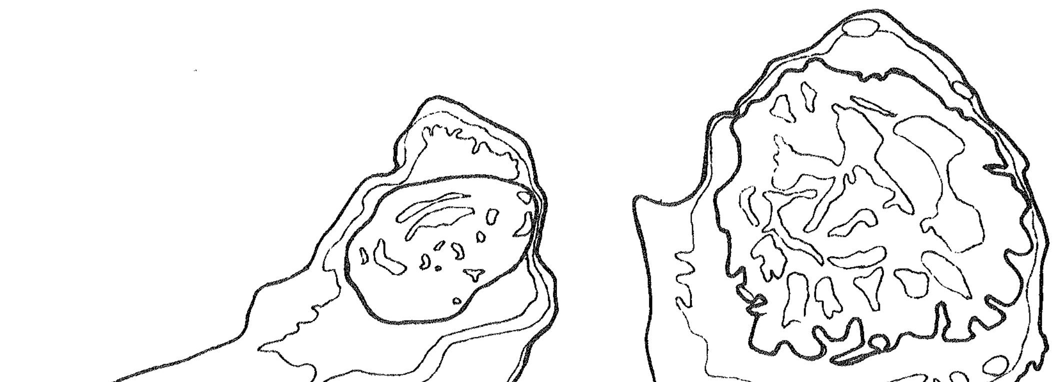
a
b
c
d
e
f
g
h
i

Fig.29.

Gonads of *Patiriella vivipara*.

T,S. of gonad showing one free ovum and developing oocytes around the wall of the gonad.

T.S. of gonads carrying young stars.



Patiriella vivipara is the only asteroid known to exhibit embryonic development in a sac derived from the gonad.

Gross structure.

Patiriella vivipara is five armed and carries five pairs of gonads attached to the lower side of the abactinal surface. Each pair of gonads lies towards the edge of the animal near the centre line of the interradii and just radial to the interbrachial septum (fig. 28).

During early development the gonad bears some resemblance to a small bunch of grapes. As the young develop the gonad walls stretch and the original evaginations of the gonad appear as papillae on the distended walls. Further distension of the gonad sac distorts any of its original gross structure and it acts as an enclosing membrane until the young break the sac and emerge.

No gonopore or gonadal duct is present.

The gonads.

The gonad is bordered by a prominently nucleate epithelial layer. In some sections this layer or parts of it appear equivalent to a genital rachis. A sequence of

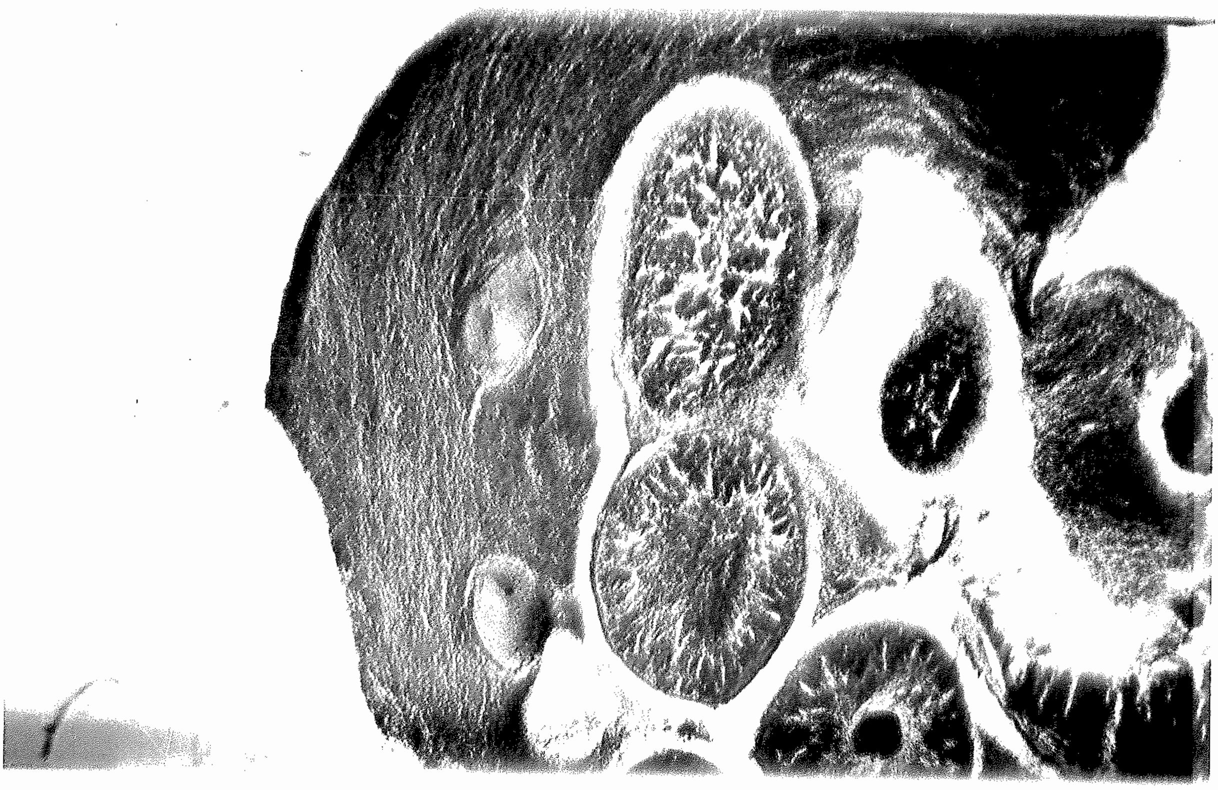


Fig.30.

Photograph of section of gonad of P.vivipara showing sperm masses and developing oocytes spermatozooid development can be followed between the gonad wall and the lumen, viz., sperm columns followed by developing spermatozooids and free spermatozoa in the lumen (fig. 30).

The origin of ova has not been observed directly in this study. It is supposed that ovum differentiation takes place very quickly as intermediate stages have been difficult to find in sections even when sections are made of gonads taken at different times or from a series of size graded individuals.

Large oocytes embedded in the developing sperm columns are considered the only precursors observed if the oocytes are not regarded as mature until released into the lumen of the gonad along with free spermatozoa. Some later oocyte divisions have probably been observed (see fig. 31) but no earlier sizes are recorded.

In view of the work of Delavault it is apposite to record that in Asterina gibbosa regenerating gonads differentiate synchronously with the gonads already present in the animal presumably taking their precursors from the genital rachis. It is considered worth suggesting that both ovum and spermatozooids precursors are supplied to the gonad from the genital rachis in Patiriella vivipara.

It is also of interest to note that development of the gonads in any animal investigated is not synchronous suggesting that developing larvae and young may inhibit development in neighbouring gonads in the same individual. Assuming continuity of physiological communication between gonads via the coelomic fluid and by the genital ring it may be expected that inhibition act radially, neighbouring gonads being more affected than those further away.

In eighty specimens of Patiriella vivipara with R between 8 mm. and 10 mm. the gonads were examined and two groups differentiated.

1) Gonads containing definite sea stars with spicules.

2) All stages prior to definite stars.

210 of the 800 gonads were in advance of the remainder, all belonging to group 1. In 170 cases the adjacent gonads were behind in development; in 230 cases ajacent gonads were equivalent in development. In none of the specimens were all the gonads synchronous. In 30 of the 80 specimens half of the gonads belonged to group 1 and of the group 1 gonads only 20 were matched by gonads of the same group; the remaining group 1 gonads were all matched by a group 2 gonad in the same interradial area.

Further investigation of this topic would probably be interesting especially in view of the work of Chaet et al. on gamete shedding substance extracted from radial nerves and its inhibitor 'shedhibin'. Kanatani (1964) has shown also that gamete shedding substance promotes maturation of eggs. In view of the presence of fully formed stars in the gonad sac of *Patiriella vivipara* it would be of interest to see whether radial nerve extracts could promote development of group 2 gonads; whether inhibition originates from the adults or developing young and whether the inhibitor is present in the young star and not the shedding substance. Such investigation is beyond the scope of my present facilities.

Development.

Techniques: Larvae, young stars and eggs will survive for a short period in clean sea water. Unless aseptic conditions are maintained bacterial and protozoan infection will terminate the cultures. This also applies to the following culture techniques. Stars with plate development well advanced will survive in clean sea water and will continue to develop if fed.

Earlier stages appear to need some form of nutrient solution as they do not continue to develop in sea water.

Two culture solutions were employed the second being most successful.

1. Sterile sea water .... 100mls.

   Tissue culture medium 199 .... 10 mls.

Tissue culture medium 199 is supplied by the Commonwealth Serum Laboratories, Melbourne and apart from a range of nutrients carries some antibiotics.

2. Erdschreiber Medium. As employed by Fell 1946 (after Gross, 1937) the medium consists of:

Sterile sea water	1000 mls.
Soil extract	50 mls.
Sodium nitrate	0.1 gm.
Sodium hydrogen phosphate	0.02 gm.

Fell prepared soil extract by autoclaving one kilogramme of garden soil with a litre of distilled water and repeatedly boiling and filtering the aqueous extract until a clear golden brown fluid was obtained.

This author has found the medium successful when the soil extract was only boiled, not autoclaved, and tap water does not seem to be deleterious.

Eggs and larvae excised from the gonads of the parent were placed in some 4 mls. of medium in a small Petri-dish. The small container was then placed in a large Petri-dish with a wad of damp cotton wool to maintain humidity and reduce evaporation from the medium. The medium was changed every two or three days. Aseptic techniques were maintained as far as possible.

Fertilisation.

Self fertilisation appears to occur. Individuals excised from the parent gonads and kept in isolated jars of sea water produced young on attaining 5 mm. R. No evidence has been gleaned of gonad differentiation in the young star whilst still in the gonadal sac of the adult. Also, there is no evidence for free release of spermatozoa. Apart from the absence of a gonoduct spermatozoa were never shed into the surrounding medium even when the temperature was raised or when the animal was stimulated with 12 volt alternating current.

The ovum.

The egg is relatively large and yolky and, when visible, the nucleus appears to be placed towards one end

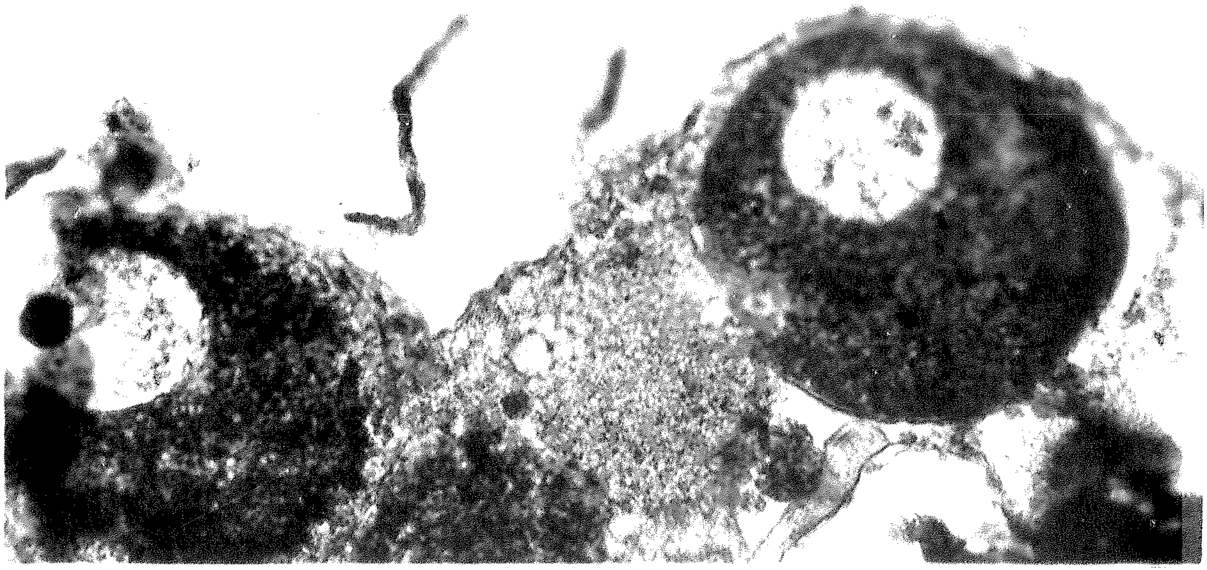


Fig.31.

Late oocytes of Patiriella vivipara.

of the cell. Eggs measured, by eyepiece micrometer, ranged from 0.155 - 0.175 mm. across the largest diameter, the nucleus being c. 0.07 mm. in diameter.

The eggs of most echinoderms are c. 75 μ in diameter (Nicholls, 1966) though some, especially those with abbreviated development, may possess eggs up to 0.5 mm. in diameter. Brooding sea stars may possess eggs attaining 2.5 mm. in diameter (Ludwig 1903 cited in Hyman 1955).

First cleavage to metamorphosis.

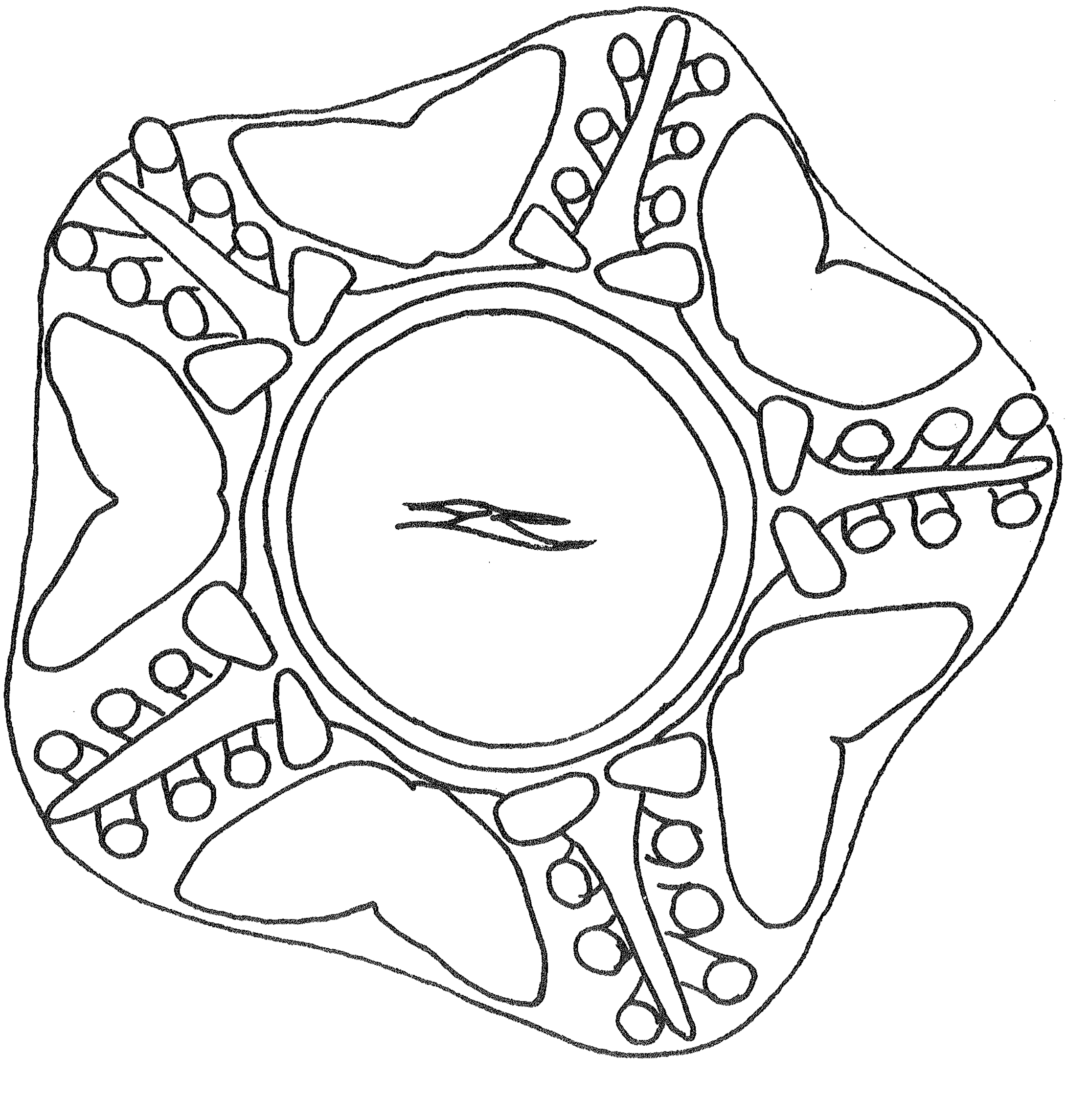
Patiriella vivipara demonstrates a shortened sequence of development from which a free living stage is absent. Details of embryology still remain to be worked out and also the derivation of tissues during development.

Cleavage is total and appears nearly equal where fertilised eggs have been observed developing for a short time. Coelom formation appears to follow closely that known in *Asterina gibbosa* (Ludwig, 1882) and the final larval form before metamorphosis appears to be a reduced brachiolaria.

Metamorphosis occurs at this stage the primordia of the definitive star then being observable. The water

Fig.32.

Patiriella vivipara; young star showing water vascular ring and definitive podia.



ring and definitive podia are observed next (fig. 32). A complete temporal sequence of events has not yet been recorded though, now that the techniques of rearing larvae are proven with this species, it is only a matter of time before a complete series is obtained.

Skeletal development.

A sequence of skeletal calcification can be followed. Each ossicle begins as a single spicule (fig. 33) that developes into a fenestrated plate (fig. 34). Eleven pieces are visible in the abactinal surface, viz., five radial ossicles followed by five interpolated interradial ossicles and a central plate.

On the actinal surface the first pairs of ambulacral ossicles can be seen as soon as the first two pairs of podia are present and new pairs of ambulacral ossicles are laid down after the formation of each pair of tube feet.

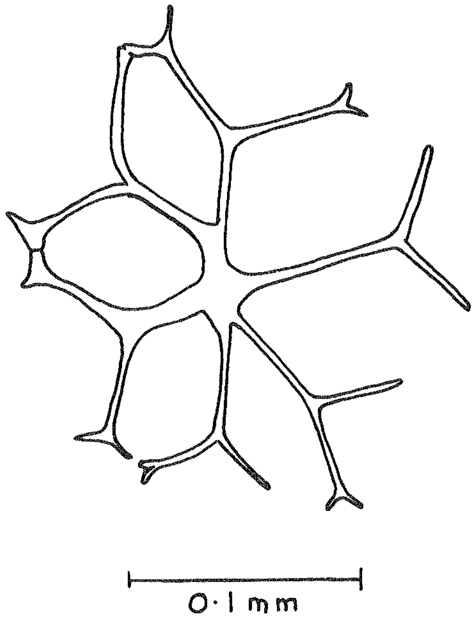
At emergence the star carries the full sequence of radial and interradial plates and ambulacral ossicles (a star of 2 mm. R possesses five pairs of ambulacral plates). Spinulation is not complete at this stage. A comparison

Fig.33.

Patiriella vivipara: early spicule.

Fig.34.

Patiriella vivipara: Fenestrated plates from centre of disc of young star. The apical plate is ommitted from this diagram. For details see text.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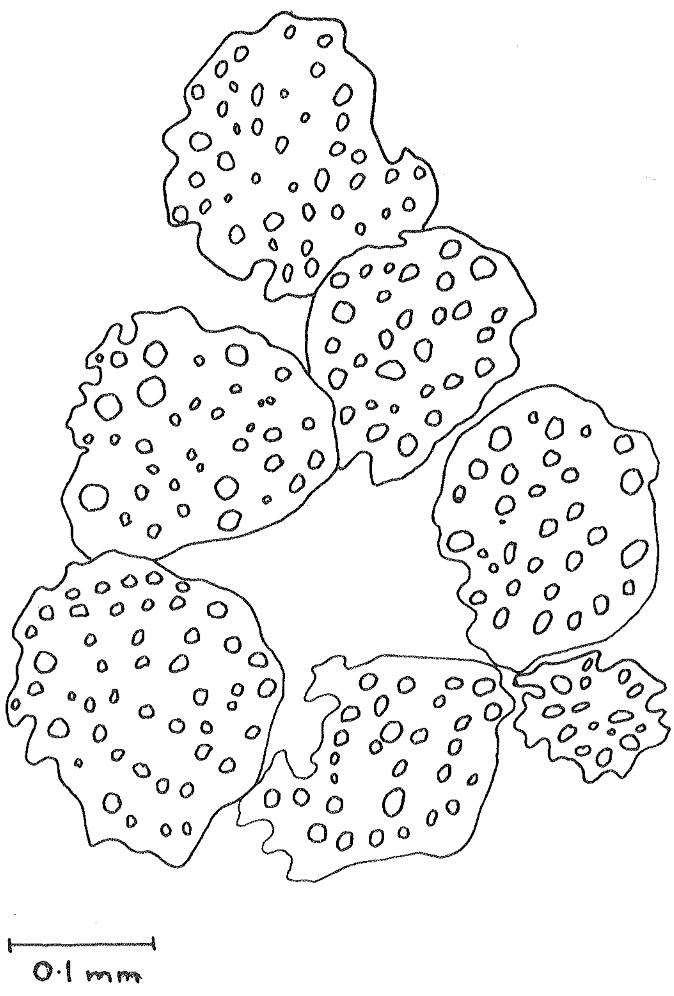
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of the spinulation of a young and mature star is given in Table II.

Table II

Spinulation of *P. vivipara* at emergence and maturity.

	R= 2mm	R= 10mm.
Number of ambulacral ossicles	5	17
No. spines / oral plate	2	6
No. furrow spines / adambulacral plate	1	2
No. actinal spines / plate at centre of interradii.	0	1
No. actinal spines / plate near edge of disc	1	2
No. spines / infero-marginal plate	2- 3	4- 5
No. spines on interradial abactinal plates	1- 2	3- 4
No. spines on radial abactinal plates	4- 5	10- 14

GROWTH TO MATURITY.

Patiriella vivipara in captivity and in the field appears to grow at a rate of 1 mm radially per lunar month attaining its maximum size at 14 - 15 mm. R. Breeding appears to be continuous from a size of 5 mm R onwards, the final batch of young stars often emerging through the decrepit skeleton of the recently dead adult star. Thus *P. vivipara* appears to live for approximately one year.

No figures are available for the other species though aquarium maintained *Patiriella regularis* reached a size of 25 mm. R after nine calender months having been placed in the tank at c. 10 mm. R. It is presumed that the larger species of *Patiriella* live longer than one year perhaps taking that time to reach maturity. No evidence is available for the longevity of *Patiriella exigua*.

BREEDING SEASONS.

Patiriella vivipara - throughout the year.
Patiriella exigua - throughout the year (Mortensen, 1921)
Patiriella regularis- mainly October to May. Some individuals possess mature gonads at all seasons.
Patiriella calcar, gunnii and *brevispina* - No adequate information.

MODES OF REPRODUCTION.

Patiriella vivipara - Viviparous; coelomic incubation; hermaphrodite; presumed self fertilising.

Patiriella exigua - Dioecious; with orally directed gonopores. Eggs attached to substrate; shortened development (Mortensen, 1921).

Patiriella regularis - Dioecious; gonopores in both sexes directed aborally. Free swimming larvae. Crump (pers. comm.) says that the free swimming bipinnaria stage is short and settlement and metamorphosis takes place after approximately two days.

Patiriella calcar, gunnii and brevispina - Dioecious; gonopores in both sexes directed aborally. Presumed free swimming larvae. No details.

ASEXUAL REPRODUCTION.

In no individual of any of the Tasmanian species of Patiriella has fissiparity been observed. Any irregularity in symmetry has obviously been due to damage at some stage in development.

The only reference that I can find to fissiparity is in Bennett, 1927 where he says (p. 148) "...... the fact of autotomy is generally admitted (e.g. in the Australian species A. anomala, A. wega and A. exigua).....". On the same page Bennett also produced evidence of autotomy in

Patiriella regularis but in my opinion he only provided an expression of anomalies in the numbers of rays and madreporites present. A.M. Clark (1967) includes no *Patiriella* species in her list of species of Asterozoa recorded as fissiparous.

In the opinion of this author the Tasmanian species of *Patiriella* are not fissiparous and no evidence has been found of asexual reproduction within the genus.

MORPHOLOGICAL VARIATION.

Variation in the morphology of asterinid sea stars of the genus *Patiriella* has rarely been recorded in the literature. Mortensen (1925) described two varieties of *Patiriella regularis* from New Zealand on the arrangement of the abactinal plates and their associated spines. H.L. Clark (1938) made some comments on the numbers of rays in individuals from various populations of *Patiriella exigua*, *Patiriella calcar*, *Patiriella gunnii* and *Patiriella brevispina*. Quite large samples of *P. exigua* were available to him and he demonstrated that, in his samples, *P. exigua* showed less variation in the number of rays on Lord Howe Island than in the Torres Strait, viz., 2 - 2.5 % non-pentamerous variants were present in the Lord Howe populations and some 8 % in the samples from the Strait.

Clark suggested that *P. exigua* reached Lord Howe Is. comparatively recently and that living under less favoured conditions the variants were more often eliminated from the population.

Variation has only been studied here it affects taxonomic characters and some considerations follow.

BODY PROPORTIONS.

The size and shape of the sea star body are expressed as ratios of the dimensions *R* (the major radius), *r* (the minor radius) and *vh* (the vertical height of the body). Each dimension is recorded in millimetres.

Patiriella regularis. In a sample of 289 specimens of *P. regularis* from Bellerive the ratio of R : r ranged between 2.0 - 1.2 : 1, i.e. from bluntly pentagonal in body outline to stellate form. The number of individuals in each group of form is expressed in fig. 35; the bulk of the sample between 1.4 : 1 and 1.7 : 1 being the form recorded for 65.05 %.

Patiriella vivipara. Distribution of form in a sample of 112 specimens of *P. vivipara* from Midway Point is demonstrated (fig. 36). This species is more blunt and nearly pentagonal than the sample of *Patiriella regularis* so treated. 48.2 % of the sample of *P. vivipara* fall within the 1.2 - 1.3 : 1 group of the proportions R : r.

Form and shape as related to the number of rays of individuals of the five species groups are shown in the following table.

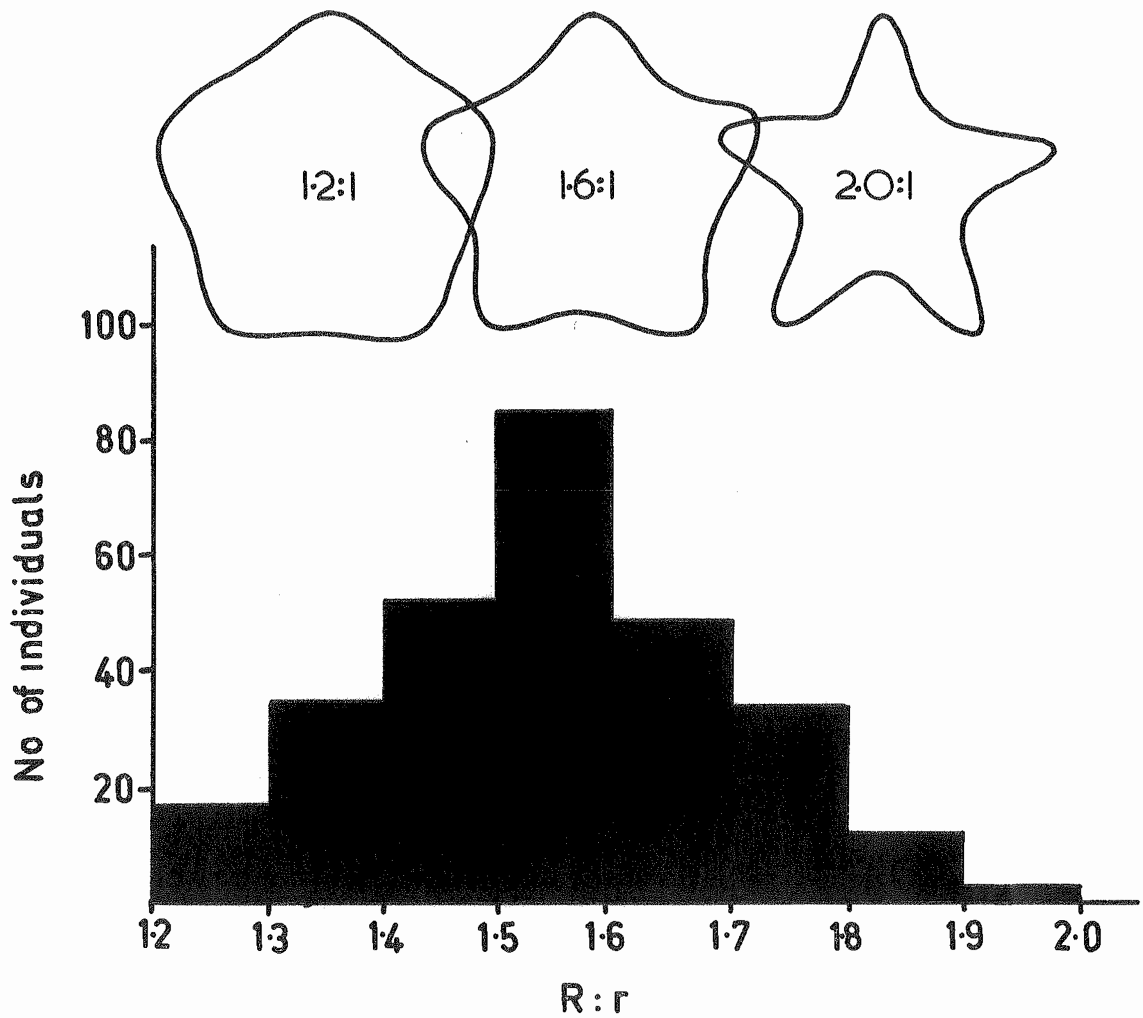
Table III.

Species	Size of sample	Range R : r	Mean	No. of Rays
P. *exigua*	10	1.05 - 1.07	1.06	4
	238	1.06 - 1.43	1.29	5
	4	1.09 - 1.50	1.24	6
P. *vivipara*	2014	1.00 - 1.60	1.25	5
	2	1.20 - 1.25	1.225	6
P. *regularis*	3	1.33 - 2.00	1.73	4
	254	1.20 - 2.00	1.60	5
	12	1.20 - 1.67	1.45	6
	1	---- 1.69 ----		7
	1	---- 1.41 ----		8
P. *gunnii/ brevispina*	25	1.15 - 1.37	1.23	6
	6	1.18 - 1.38	1.26	7
P. *calcar*	3	1.42 - 1.52	1.45	7
	64	1.21 - 1.75	1.37	8
	4	1.50 - 1.52	1.51	9

Fig.35.

Patiriella regularis: Distribution of body shape expressed as the ratio R:r in a sample of 289 specimens from Bellerive, Tasmania.

The extreme and median forms are illustrated above the histogram.

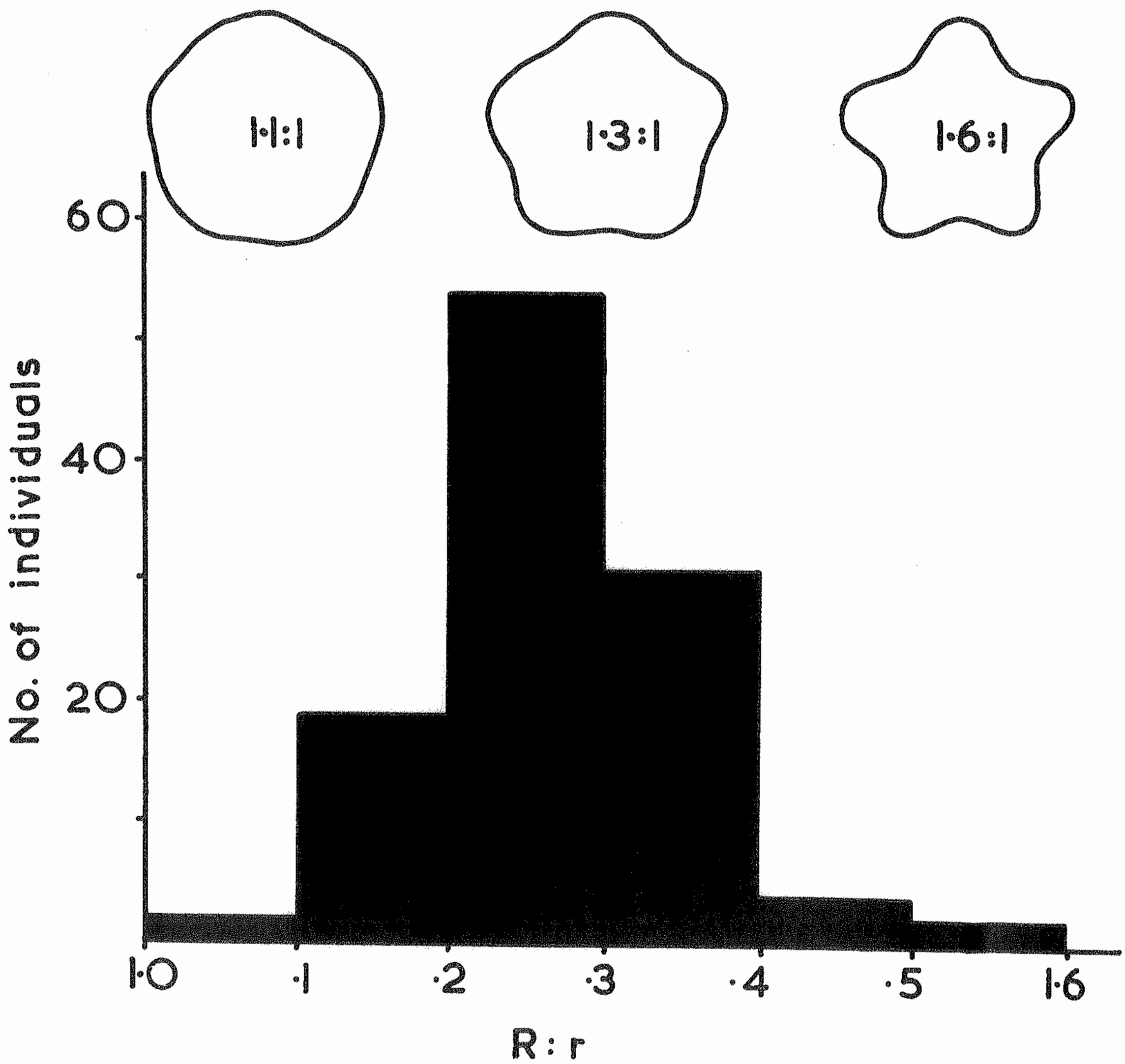


1·2:1
1·6:1
2·0:1
100
80
60
40
20
No of individuals
1·2
1·3
1·4
1·5
1·6
1·7
1·8
1·9
2·0
R : r

Fig.36.

Patiriella vivipara: Distribution of body shape expressed as the ratio R:r in a sample of 112 specimens from Midway Point, Tasmania.

The extreme and median forms are illustrated above the histogram.



1·1:1
1·3:1
1·6:1
60
40
20
No. of individuals
1·0
·1
·2
·3
·4
·5
1·6
R : r

Variation in the spinulation of the oral plates of *Patiriella calcar*.

One of the primary divisions of H.L. Clark's (1946) key to the genus *Patiriella* is "A. Rays normally more than five : no suboral spines on the oral plates.". The group of species selected by this choice of characters includes *Patiriella gunnii*, *P. brevispina* and *P. calcar*. In Tasmanian material, at least, the lack of suboral spines is considered an unreliable characteristic with which to distinguish *P. calcar*, - suboral spines being found on at least one, all or combinations of oral plates within any one specimen. Conversely, no specimens of the "gunnii" fascies have been observed, by this author, to carry suboral spines.

The distribution of suboral spines in a sample of 199 specimens of *P. calcar* taken from all round the Tasmanian coastline is shown in Table IV . 37.6 % of the sample possess in one combination or another, suboral spines on some oral plates. It is interesting to note that of the eight rayed specimens more individuals carry a larger complement of suboral spines. 12 specimens of the 156 with eight rays (i.e. 7.6 % of the subsample) carried suboral spines on their full complement of oral plates.

No. of rays.	No. of specimens	No. of specimens with one suboral spine on x plates.																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	x
8	56	6	7		2	2	4	5	2	1	2	2	4		3	4	12			
9	6				1	1			1								1		2	
10	3	1	2																	
11	1				1															
Total	66																			
		No. of specimens with two suboral spines on x plates.																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	x
8	8	1	2	2	3															
10	1		1																	
Total	9																			

Table IV

The spinulation of the oral plates of *Patiriella exigua*.

H.L. Clark's (1946) key to *Patiriella* uses as the introductory character to its final couplet "CC. 2 or more suboral spines, though there may be but one on some plates:". This couplet distinguishes *Patiriella inornata* Livingstone and *Patiriella exigua*. In very few Tasmanian specimens of *P. exigua* are paired suboral spines present on oral plates. The distribution of suboral spines in a sample of Tasmanian *P. exigua* is shown in Table V.

Table V.

Distribution of suboral spines in a sample of 107 Tasmanian *P. exigua*.

	No. of specimens with spines on *x* suboral plates.											
x	0	1	2	3	4	5	6	7	8	9	10	Total
One spine / oral plate					1		1		1	2	102	107
Two spines / oral plate			1									1

Thus 102 individuals of 107 carried a full complement of a single suboral spine on each oral plate.

Only one individual had paired suboral spines and then on only two oral plates.

Variation as it affects the specific identy of *Patiriella brevispina* and *Patiriella gunnii*.

Patiriella brevispina H.L. Clark was described as a very distinctive form in the field being six armed and deep purple in colour. It has proven difficult, however, to distinguish that species from *Patiriella gunnii* Gray in preserved material. A.M. Clark (1966) queried the specific identity of *P. brevispina*. H.L. Clark, himself, queried the validity of the species he described and named (1938) and reiterated his reservations in 1946. Miss A.M. Clark's comments and the inadequate description of "*Asterina*" *gunnii* offered by Gray (1840 and 1866) prompted an investigation into the characteristics of the material available showing the fascies of "gunnii/brevispina". A redescription and designation of a lectotype of *Patiriella gunnii* is offered in a previous section.

Excluding the lectotypes of *Patiriella gunnii* 194 specimens were available for study. Due to the scarcity of Tasmanian material specimens from outside the state were gathered together and samples from Western Australia, South Australia, Victoria and N.S.W. are included.

Choice of characteristics from the material available was determined as follows.

1) Size and shape. Size, expressed by the radial measurement R was considered because it is the only readily available dimension that reflects growth. Height of the body, measured from the plane of the actinal surface to the top of the disc (expressed as vh.) was also considered because field observations and discussion postulated arched and flattened forms.

2) Spinulation of the ambulacral groove and ajacent plate series. Considered in this case because the spines of the ambulacral groove can logically be regarded as a functional mechanical unit. Extremes in numbers and size of spines might be assumed inefficient in the region of the ambitus.

3) Spinulation of the actinal surface was considered because H.L. Clark placed some emphasis on the very short actinal intermedeate spines in Patiriella brevispina.

Preliminary observations indicated that many specimens of the "gunnii" fascies carried diplacanthid subambulacral spines on the adambulacral plates. H.L. Clark's (1938) description of Patiriella brevispina is precise -

"a single, subambulacral spine". This generalisation is substantially correct, not withstanding that one specimen of _P. brevispina_ (paratype, Australian Museum Reg. No. J6181) carries two subambulacral spines on one or two adambulacral plates near to the mouth.

The specimens were listed and the factors to be considered measured or counted. A list of the material available is shown in Table VI.

A subjective species determination was made, splitting the whole sample into two lots. This determination is recorded in the table. G ≡ _P. gunnii_; B ≡ _P. brevispina_.

Collection numbers are given where available. E.P.H. refers to Dr. E.P. Hodgkins collection from the Zoology Department of the University of Western Australia.

Table VI.

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
1.	Jervoise Groyne, Cockburn Sound, W.A.	1	Flattened tip to innermost oral spines. (E.P.H.)	B
2.	Burnie, Tasmania.	1	"	B
3.	Woodman's Pt., W.A.	1	" (E.P.H.)	B
4.	Woodman's Pt., W.A.	1	" "	B
5.	Cockbourne Sound, W.A.	1	" "	B
6.	Dunborough, W.A.	1	Innermost oral spines flattened and almost bifurcate at tip. (E.P.H.)	B
7.	Jervoise Groyne, W.A.	1	" (E.P.H.)	B
8.	Woodman's Pt., W.A.	1	" (E.P.H.)	B
9.	Jervoise Groyne, W.A.	1	Oral spines flattened, (E.P.H.)	B
10.	Woodman's Pt., W.A.	1	" (E.P.H.)	B
11.	Jervoise Groyne, W.A.	1	" (E.P.H.)	B

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
12.	Green's Beach, Taxmania.	1		B
13.	Green's Beach, Tasmania.	1		B
14.	Green's Beach, Tasmania.	1	Oral spines slightly flattened.	B
15.	Green's Beach, Tasmania.	2		G
16.	Green's Beach, Tasmania.	1	Oral spines slightly flattened.	
17.	Green's Beach, Tasmania.	1		
18.	3 m. off Glenelg, S.A.	1	Oral spines very flattened.	B
19.	3 m. off Glenelg, S.A.	1	Oral spines flattened, almost bifurcate with extraneous knobs.	B
20.	Long Pt., Maria Is., Tasmania.	2		G
21.	Long Pt., Maria Is., Tasmania.	2		G
22.	Low Head, Tasmania.	1	First subambulacral spines paired.	G
23.	Low Head, Tasmania.	2		G

No.	Locality	No. of sub. amb. spines	Comments		Subjective species det.
24.	Green's Beach, Tasmania.	1	Oral spines slightly flattened.		B
25.	Green's Beach, Tasmania.	1			B
26.	Green's Beach, Tasmania.	2			G
27.	Green's Beach, Tasmania.	2			G
28.	Green's Beach, Tasmania.	1			B
29.	St. Vincent Gulf, S.A.	2			G
30.	Cottesloe, W.A.	2	Oral spines slightly flattened.		G
31.	Cottesloe, W.A.	2	"		G
32.	Jervoise Groyne, W.A.	1		(E.P.H.)	B
33.	"	1		"	B
34.	"	1		"	B
35.	"	1		"	B
36.	"	1		"	B
37.	"	1		"	B

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
38.	St. Vincent Gulf, S.A.	1		B
39.	Schnapper Pt., Victoria.	1	Nat. Mus. Vict. H87.	B
40.	Victoria.	2	" H89.	G
41.	Victoria.	2	"	G
42.	Victoria.	1	"	?
43.	Port Phillip Heads, Victoria	1	Nat. Mus. Vict. H97.	B
44.	"	1	Nat. Mus. Vict. H91.	B
45.	Western Port, Victoria.	2	Nat. Mus. Vict. H88.	G
46.	Port Phillip Bay, Victoria.	2	Nat. Mus. Vict. H86.	G
47.	Woodman's Pt., W.A.	1	(E.P.H.)	B
48.	Jervoise Groyne, W.A.	1	"	B
49.	Jervoise Groyne, W.A.	2	"	G

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
50.	Cheyne Beach, W.A.	2	(E.P.H.)	G
51.	Jervoise Groyne, W.A.	1	"	B
52.	Woodman's Pt., W.A.	1	"	B
53.	Freemantle, W.A.	1	"	B
54.	Jervoise Groyne, W.A.	1	"	B
55.	Dunsborough, W.A.	1	"	B
56.	Jervoise Groyne, W.A.	1	"	B
57.	"	1	"	B
58.	"	1	"	B
59.	Woodman's Pt., W.A.	1	"	B
60.		1	"	B
61.		1	"	B
62.		1	"	B

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
63.	Trigg Island, W.A.	2	(E.P.H.)	G
64.	Cockburn Sound, W.A.	1	"	B
65.	Jervoise Groyne, W.A.	2	"	G
66.	"	1	"	B
67.	"	2	"	G
68.	"	1	"	B
69.	"	2	"	G
70.	"	1	"	B
71.	"	1	"	B
72.	"	2	"	G
73.	"	2	"	G
74.	"	2	"	G
75.	"	2	"	G

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
76.	Jervoise Groyne, W.A.	2	Paired subambulacrals not (E.P.H.) a complete series orally.	G
77.	"	2	"	G
78.	"	2	"	G
79.	"	2	"	G
80.	Yauchep Beach, W.A.	2	"	G
81.	"	2	"	G
82.	"	1	"	B
83.	Eagle Bay, W.A.	2	"	G
84.	"	2	"	G
85.	Cape Naturaliste, W.A.	1	R = 10 mm. "	B?
86.	Port Gregory, W.A.	2	"	G
87.	"	1	"	G

No.	Locality	No. of sub.amb. spines	Comments	Subjective species det.
88.	Port Gregory, W.A.	2	(E.P.H.)	G
89.	Cheyne Beach, W.A.	2	"	G
90.	"	2	"	G
91.	"	2	"	G
92.	"	2	"	G
93.	Woodman's Pt., W.A.	2	"	G
94.	"	2	"	G
95.	"	2	"	G
96.	"	2	"	G
97.	"	1	2 subambulacrals on first adambulacral plate "	G ?
98.	"	1	"	B
99.	"	1	"	B
100.	"	2	"	G

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
101.	Cottesloe, W.A.	1	(E.P.H.)	G ?
102.	"	1	"	G ?
103.	"	1	"	G ?
104.	"	2	"	G
105.	"	2	"	G
106.	Cottesloe Reef, W.A.	2	"	G
107.	"	2	"	G
108.	"	1	"	G ?
109.	"	2	"	G
110.	"	1	"	G
111.	"	2	"	G
112.	Trigg Island, W.A.	2	"	G
113.	"	2	"	G

No.	Locality	No. of Sub. amb. spines	Comments	Subjective species det.
114.	Trigg Island, W.A.	2	(E.P.H.)	G
115.	"	2	"	G
116.	"	2	"	G
117.	"	2	"	G
118.	"	1	"	G ?
119.	"	1	"	G ?
120.	"	2	"	G
121.	"	2	"	G
122.	"	2	"	G
123.	"	2	"	G
124.	Rottnest, W.A.	2	"	G
125.	"	1	"	B
126.	"	2	"	G

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
127.	Rottnest, W.A.	1	(E.P.H.)	B
128.	"	1	"	B
129.	"	2	"	G
130.	"	2	"	G
131.	"	2	"	G
132.	"	2	"	G
133.	"	2	"	G
134.	"	2	"	G
135.	Armstrong Pt., Rottnest, W.A.	2	"	G
136.	Albany, W.A.	2	Australian Museum, J3981.	G
137.	"	2	"	G
138.	"	2	"	G
139.	"	2	"	G

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
140.	Albany, W.A.	2	Australian Museum, J3981.	G
141.	"	2	"	G
142.	"	2	"	G
143.	"	2	"	G
144.	"	2	"	G
145.	Shell Harbour, N.S.W.	2	Australian Museum, J4795.	G
146.	"	2	"	G
147.	"	2	"	G
148.	"	2	"	G
149.	Collaroy, N.S.W.	2		G
150.	"	2		G
151.	"	2		G
152.	"	2		G

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
153.	Lord Howe Island.	2	Australian Museum, G11519	G
154.	Koombana Bay, Bunbury, W.A.	1	Aust. Mus. J6181, paratype.	B
155.	Glenelg, W.A.	1	Aust.Mus. J7533.	B
156.	"	1	"	B
157.	South Coast, W.A.	1	Aust. Mus. J6780.	B
158.	Walkerville, Victoria.	1	Aust. Mus. J6753.	B
159.	"	1	"	B
160.	Sandon River, N.S.W.	2	Aust. Mus. J6399.	G
161.	"	2	"	G
162.	Lille Bay, nr. Sydney, N.S.W.	2	Aust. Mus. J4794.	G
163.	"	2	"	G
164.	"	2	"	G
165.	"	2	"	G

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
166.	Fremantle, W.A.	2		G
167.	Jervoise Groyne, W.A.	2		G
168.	Altona, Victoria.	1	Aust. Mus. J5811.	B
169.	"	1	"	B
170.	"	1	"	B
171.	"	1	"	B
172.	"	1		B
173.	"	1		B
174.	"	1		B
175.	Fremantle, W.A.	1	Aust. Mus. J7435.	B
176.	Port Fairy, Victoria.	2	Aust. Mus. G7572.	G
177.	Tasmania.	1	Aust.Mus. J1857.	B
178.	Port Phillip, Victoria.	1	Aust. Mus. J5802.	B

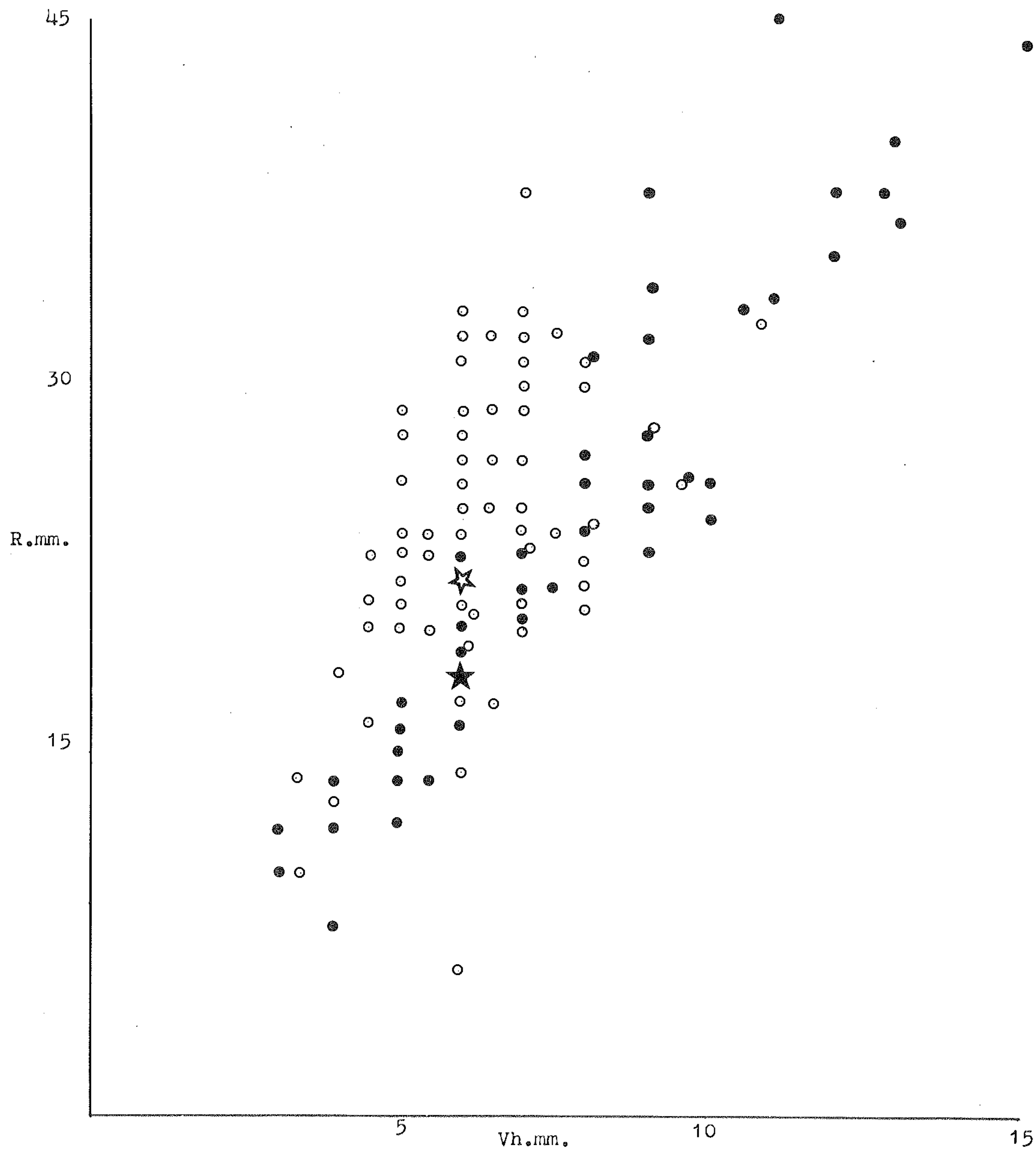
No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
179.	Port Phillip, Victoria.	1		B
180.	"	1		B
181.	"	1		B
182.	"	1		B
183.	"	1		B
184.	"	1		B
185.	"	1		B
186.	"	1		B
187.	"	1	Aust. Mus. J2315.	B
188.	Hunter Island, Bass Str.	2	Aust. Mus. J6839.	G
189.	Tasmania.	1	Aust. Mus. J1858.	B
190.	Flinders, Western Port, Vict.	2		G
191.	"	2		G

No.	Locality	No. of sub. amb. spines	Comments	Subjective species det.
192.	Flinders, Western Port, Vict.	2		G
193.	"	2		G
194.	Pt. Leo, Victoria.	1	R = 3.5 mm. Juvenile.	G ?

Fig.37.

Patiriella gunnii and Patiriella brevispina : Body proportions, R and vh, plotted and each point keyed for single or paired subambulacral spines.

Single subambulacral spines shown by closed points.
Paired subambulacral spines shown by open points.
Stars designate type specimens.


45
30
R.mm.
15
5
Vh.mm.
10
15

Body proportions (vh and R) were plotted against each other, keying each individual for single or paired subambulacral spines. Also size (R) was plotted against the number of adambulacral plates carrying three or more furrow spines in any one row of adambulacral plates. The results are shown in figures 37 and 38. The figures are not quite identical in their samples and some individuals plotted simultaneously.

Extreme size ; A proportion of the monacanthid "*brevispina*" forms attain a larger size than the diplacanthid "gunnii" forms, i.e. about 52 mm. R as opposed to c 89 mm R. (Shepherd, 1968 records maximum R for *Patiriella brevispina* of 70 mm).

R : vh : A proportion of the *gunnii* forms are more flattened in form than a *brevispina* group of similar radial size.

Some 31 "gunnii" specimens with R ranging between 13 and 38 mm. demonstrated a range of vh between 3.5 and 8 mm. (i.e. range vh : R = 0.21 - 0.26 : 1).

Twenty six "brevispina" specimens with R ranging between 7 and 42 mm. showed a range of vh between 4 and 15 mm. providing ratios of vh : R = 0.35 to 0.57 : 1. The intermediate sample of 53 specimens gave ratios between both of these samples i.e. some 42 % of the specimens to hand at that time.

Subjectively the species Patiriella brevispina appears sound but 42 % of a large sample falling between the two distinct groups appears to show that at the most the gunnii/brevispina group of Patiriella is a polymorphic single species, on this group of characteristics alone. It must be noted, however, that all the specimens were preserved, either dry or in spirit and such material is difficult to preserve in a constant way. This author doubts the accuracy of many of the measurements given on this basis.

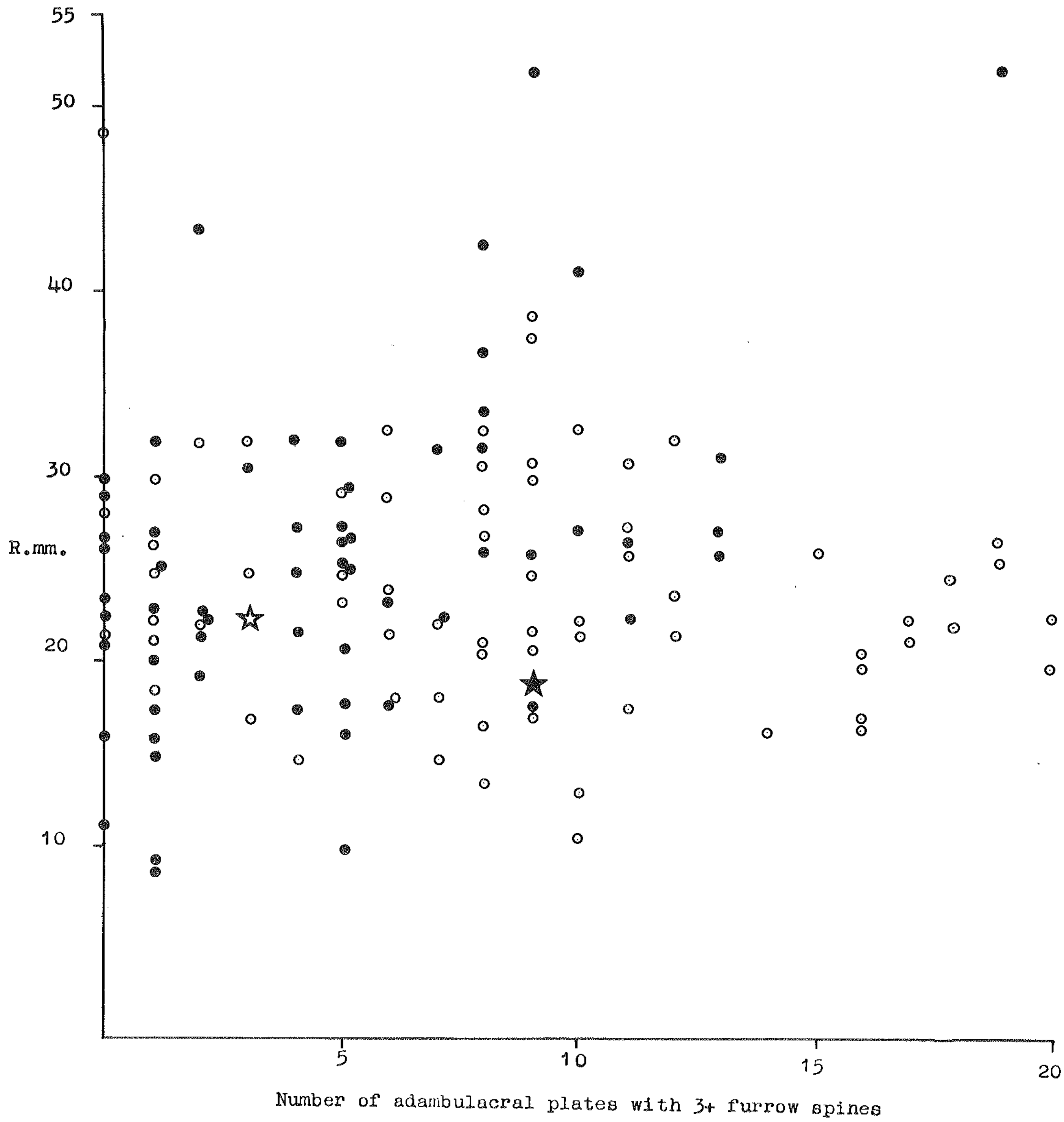
R : number of adambulacral plates with three or more furrow spines.

The observation that some specimens of the samples possessed more adambulacral plates carrying more furrow spines than other individuals is expressed graphically. An arbitary 50 % division of the area between the axes enables some analysis. 43 of the 126 points (some representing more than one specimen) showed individuals carrying more furrow spines on more adambulacral plates at a smaller size than the 85 plotted points that show individuals carrying fewer furrow

Fig.38.

<u>Patiriella</u> <u>gunnii</u> and <u>Patiriella brevispina:</u>

Size expressed as R, plotted against the number of adambulacral plates with three or more furrow spines. The points are keyed for paired and single subambulacral spines as in figure 37.



55
50
40
30
R.mm.
20
10
5
10
15
20
Number of adambulacral plates with 3+ furrow spines

spines at a similar or greater size.

Of the 43 specimens with a greater number of furrow spines 34 (26.9 % of the entire sample) could be referred to the "gunnii" group with diplacanthid subambulacral spines. Of the specimens with fewer furrow spines some 26 % could be referred to "gunnii" on subambulacral characteristics and c 41 % to "brevispina".

The furrow and subambulacral spinulation of the sample can also be expressed as in Table VII from which fig39 was also constructed. It appears from the table that the more adambulacral plates carry three or more furrow spines the more likelihood that the subambulacral spines will be diplacanthid.

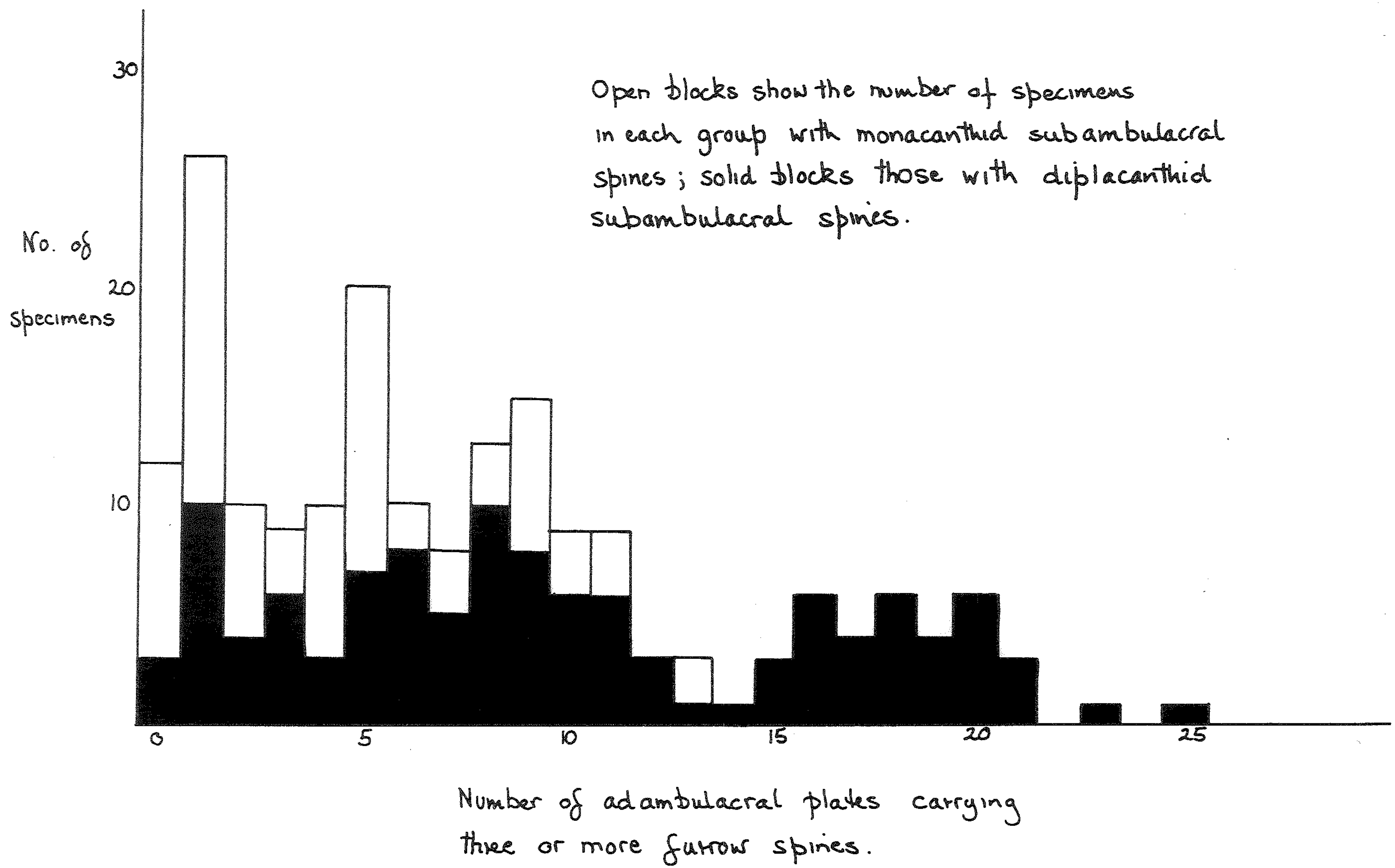
This may also correlate with the fact that the oral and ambital spines of specimens of the "gunnii" fascies are rarely extreme in form. Any "exuberance"of calcite metabolism in the "gunnii" form may produce extra spines, in the "brevispina" form extremes in spine development, even so far as developing excrescences on the spines, appears to be the rule.

TABLE VII

	DISTRIBUTION OF FURROW AND SUBAMBULACRAL SPINES IN A SAMPLE OF 194 SPECIMENS.																									
	ORAL ——— TO TIP OF RAY.																									
No. of adambulacral plates carrying three or more furrow spines.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No. of specimens showing the above character.	12	26	10	9	10	20	10	8	13	15	9	9	3	5	1	3	6	4	6	4	6	3	-	1	-	1
	Total 194.																									
No. of specimens in each group with diplacanthid subambulacral spines.	3	10	4	6	3	7	8	5	10	8	6	6	3	1	1	3	6	4	6	4	6	3	-	1	-	1
	Total 115.																									
No. of specimens in each group with monacanthid subambulacral spines.	9	16	6	3	7	13	2	3	3	7	3	3	-	4	-	-	-	-	-	-	-	-	-	-	-	-
	Total 79.																									

Fig.39.

Distribution of furrow and subambulacral spinulation in "*gunnii*" forms.



30
20
10
No. of
specimens
0
5
10
15
20
25
Open blocks show the number of specimens in each group with monacanthid subambulacral spines; solid blocks those with diplacanthid subambulacral spines.
Number of adambulacral plates carrying three or more furrow spines.

<u>Actinal intermediate spines</u> : A.M. Clark (1966) investigated the length of the actinal spines of 10 specimens of <u>Patiriella gunnii</u> (designated by Gray) because H.L. Clark (1936) laid some weight on the shorter, flatter and more truncate actinal spines of <u>Patiriella brevispina</u>. A.M. Clark found no correlation between the flattening of the subambulacral spines and the shortness of the actinal ones. She also noted that "it remains to be seen from examination of specimens retaining their natural colour whether or not there is any correlation between that and the proportions of the spines.".

Ten spines from the middle of the interradii of 35 specimens were measured, averaged and their size distribution plotted. The length of the spines plotted ranged between 0.24 mm. and 1.15 mm. Eleven of the specimens showed "<u>gunnii</u>" characteristics being chosen from the extremes of the samples previously considered and the length of the actinal intermediate spines in these specimens ranged from 0.41 mm. to 1.15 mm; the remaining 24 <u>brevispina</u> demonstrated a size range for the actinal spines measured between 0.24 mm. and 0.98 mm., a difference in absolute magnitude of 0.17 mm.

However, when the full series of specimens available were sampled and plotted all came within the range of the previous samples. Direct correlation between supposed "<u>gunnii</u>" and "<u>brevispina</u>" fractions disappeared and a nearly normal distribution curve of the spines throughout the entire sample resulted showing no evidence of two distribution groupings.

However, since the time when the large sample of material was available, more Tasmanian material has come to hand. On the basis of the previous analysis of furrow and subambulacral spinulation *Patiriella brevispina* was predicted to occur on the north coast of Tasmania. Collecting at Cape Portland in March 1969 amply bore this out when both *Patiriella gunnii* and *P. brevispina* were obtained from the littoral zone enabling full colour notes to be taken by the author.

Tabular analysis follows. Table VIII.

Colour	R : r	R : rh	No. of adambulacral plates carrying three furrow spines.	Subambulacral spines monacanthid or diplacanthid.
Purple on both surfaces. With orange tube feet.	1.26	2.24	2	1
	1.39	2.5	3	1
	1.14	2.67	5	1
Abactinal surface blotched, pale pink and purple. Light coloured actinal surface. Pale straw coloured tube feet.	1.2	3	10	2
	1.2	3.43	20	2
	1.33	3.3	18	2
	1.3	3.7	15	2
	1.5	3.0	10	2
	1.3	2.9	12	2

Table VIII

In my opinion, on the characteristics of the samples considered, there is evidence enough to validate the separate specific ranks of *Patiriella gunnii* and *Patiriella brevispina*.

Comments on variation and on the reliability of spine characteristics as taxonomic characters in the genus *Patiriella*.

Traditionally asteroids have been described and their relationships elucidated on the basis of easily examined morphological characters. This is certainly not satisfactory when species pairs such as *Patiriella exigua/vivipara* and *Patiriella gunnii/brevispina* are considered. When dried specimens are used for comparative purposes differences are certainly not obvious and without adequate field data specific determination is difficult.

It appears that in order to elucidate the interrelationships of the species within the genus *Patiriella*, and probably within the Asterininae, basic information will need to be gathered under the following headings :

1) Development of calcification.

Development of calcification in embryos, larvae and young of many echinoderms is known (Raup, 1966) but detailed information about the rate and control of calcification remains unknown. Until detailed studies of calcium metabolism, under varied conditions, are carried out on echinoderms the formation and significance of much asteroid "ornament" external to the structural plates of the skeleton remain unknown.

It would be particularly interesting to have information available on the pathways and control of calcium metabolism in *Patiriella gunnii* and *Patiriella brevispina*. The adults are differentiated upon the characteristic pattern and form of the spines and there is some indication that *P. gunnii* accumulates extra spines during growth whilst *P. brevispina* adds to its basic spine pattern.

In the case of these two species the smaller specimens (i.e. of 10 mm. R and under) are very similar. Also in the large sample of "*gunnii*" material previously considered a high proportion showed intermediate characters between the two extremes of form. Intermediates (perhaps hybrids) were most obvious at one extreme of the geographic range (i.e. Western Australia, from which, incidentally, the largest series of material was obtained). These facts lead one to postulate whether the young are comparatively undifferentiated and receive their characterics of form and colour through environmental control.

2) Reproduction.

Reproductive isolation would be adequate to separate the species of *Patiriella*. *Patiriella exigua* and *Patiriella vivipara* are obviously reproductively isolated and *Patiriella regularis* is geographically isolated from any of its generic congeners except in S.E. Tasmania. There is no evidence of hybridisation and histological differences have not been detected in examination of the gonads.

3) Ecology and distribution.

Patiriella vivipara and *Patiriella exigua* are effectively separated ecologically; *Patiriella calcar* and *Patiriella regularis* are only taken together in S.E. Tasmania. *Patiriella brevispina* is inferred to be separated from *Patiriella gunnii* by habitat and feeding (Dakin, 1952; Shepherd, 1968). In Tasmania whenever *P. brevispina* has been found *P. gunnii* is also present. Food preferences or specificity may eliminate interspecific competition but the information available is hardly detailed and in some ways even contradictory demonstrating the need for a detailed study of at least the "*gunnii*" forms throughout their range.

Variation as elucidated has only served to eliminate confusion over choice of characters employed for specific discrimination. Mortensen's two varieties of *Patiriella regularis* and Fell's publication of two extremes of form are of little value because they are not critical examinations of characters in a given population.

PART 111.

BIOGEOGRAPHY OF PATIRIELLA IN THE SOUTHERN HEMISPHERE.

The genus *Patiriella* as defined earlier in this account comprises 10 species in the southern hemisphere.

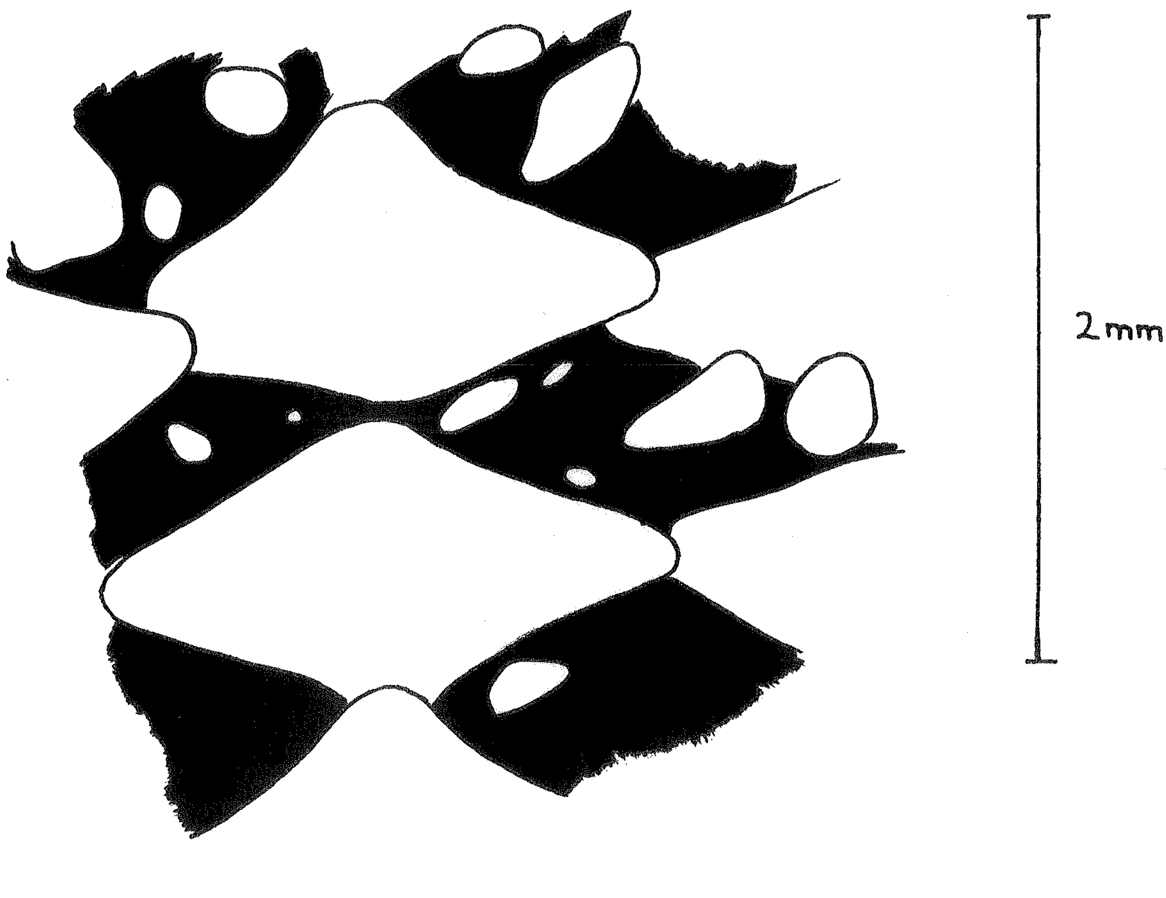
Species	Author	Distribution
P. exigua	(Lamarck)	Australia, Indo Pacific, S. Africa.
P. vivipara	Dartnall	Tasmania.
P. calcar	Lamarck	Australia.
P. regularis	(Verrill)	New Zealand, (Tasmania).
P. nigra	H.L.Clark	Lord Howe Is.
P. inornata	Livingstone	Western Australia.
P. oliveri	Bentham	North Island of New Zealand.
P. calcarata	(Perrier)	Juan Fernandez Islands.
P. gunnii	(Gray)	Australia and Lord Howe Is.
P. brevispina	H.L.Clark	Australia.

Patiriella mimica Livingstone is not included as this author has placed it in the synonomy of *Patiriella regularis* Verrill.

Patiriella (*Asterina*) *fimbriata* (Perrier) is not, in the opinion of this author, a member of the genus Patiriella on the form of the abactinal spines and the

Fig.40.

Carinal abactinal plates of "*Patiriella*"*fimbriata*.


2mm

shape of the carinal row of abactinal plates (fig. 40). Thus it is excluded from the discussion.

Patiriella inornata Livingstone is included because this author has no evidence to validate, or otherwise, its generic placing.

It is apparent from the list that Australia possesses the largest number of species of Patiriella. One species (Patiriella exigua (Lamarck)) if not of Indo Pacific origin, has certainly radiated from this centre at the same stage and further extension of its range is to be expected.

If one accepts the view that the echinoderm fauna of Australia originated in the Indo Pacific; that speciation then took place around the coasts with endemic species becoming more common as the observer moves south; and that further distribution around the Southern Hemisphere was aided by the winds and currents of the West Wind Drift there is no need for contrary arguments (see Fell, 1962 (6), 1967).

It is interesting to note that Patiriella exigua actively extending its range westwards in subtropics of the Atlantic does not appear to be completing an easterly circuit of higher latitudes. The species of Patiriella remote from the continent of Australia and the island of

Tasmania fall into a) the _exigua_ group - containing _P. exigua_ and b) the _regularis_ group.

In the latter _Patiriella nigra_ is found on Lord Howe Island, _Patiriella oliveri_ at the Kermadec Is. in New Zealand and _Patiriella calcarata_ off S. America.

Livingstone placed his _Patiriella inornata_ close to _Patiriella calcar_ and if that be correct the following generalisations might be made.

a) The group, as at present defined, originated in the Indo Pacific area.

b) Within Australia the greatest proliferation of species occurred, southwards and westwards along the east and south coasts.

c) Movement westwards in low latitudes has been accomplished by the _exigua_ group, itself speciating at high latitudes.

d) Movement eastwards and subsequent speciation has been more successful, at least, for the _regularis_ group of species, in high latitudes.

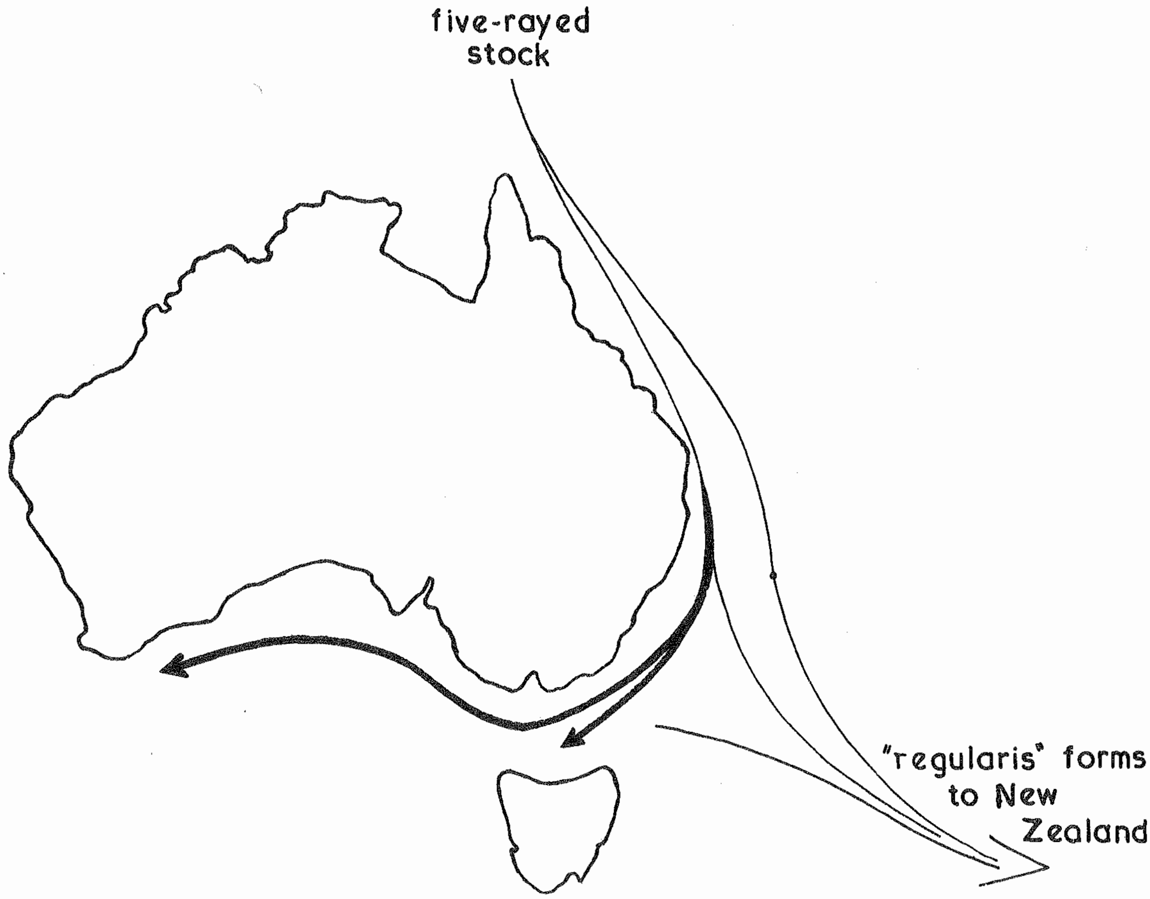
e) The extreme morphological forms _Patiriella calcar_, _Patiriella gunnii_ and _Patiriella brevispina_ are restricted to Australia and attain their greatest development along the southern coasts of the Australian continent.

True generalisations cannot be made for _Patiriella_ *nigra* and *Patiriella inornata*. If *P. inornata* is a valid species it provides the only example of a five rayed "regularis" form known from Western Australia.

Patiriella nigra, very similar morphologically to *Patiriella regularis*, is known from few specimens. Collecting on Lord Howe Is. in October 1968 revealed that it is not a common form and only one specimen was taken, a few months later, by a local resident. It might be possible to postulate an alternative route of dispersal for the "regularis" type *Patiriella* which would obviate the need for the pentamous forms to colonise south and eastern Australia before moving eastwards to New Zealand. Both routes are demonstrated in fig. 40.

Fig.41.

Proposed dispersal routes of forms of Patiriella assuming entrance to Australia from the north. Differentiation of forms with more than five rays is shown by the thickened line. Patiriella exigua is dealt with in an earlier figure. As that species is assumed to have evolved only one sibling (P.vivipara) and the extension of range of that species is not significant at this scale it is not included.


five-rayed
stock
"regularis" forms
to New
Zealand

PART IV.

PROSPECTUS FOR AN EVENTUAL REVISION OF THE ASTERINIDAE.

The family Asterinidae is in great need of revision. This comment has been repeated often during the last seventy years.

Verrill (1913) reviewed the subfamily Asterininae and unhappily this review has proven a stumbling block to subsequent taxonomists. Various writers have either bypassed the problems posed by the group or stated the position and left well alone (see Fisher, 1911 and Madsen, 1956). The work carried out so far has convinced this author that the methods commonly employed for the taxonomic study of Asteroidea are inadequate in the case of the family Asterinidae. This thesis has enabled the author to propose methods of investigation for future use.

I wish to propose here a prospectus, for future study of the Asterinidae, to produce the information needed for eventual revision of the family. It can be seen from figure 41 that the Australian worker is in an enviable position with more genera of Asterinidae found around Australia than elsewhere.

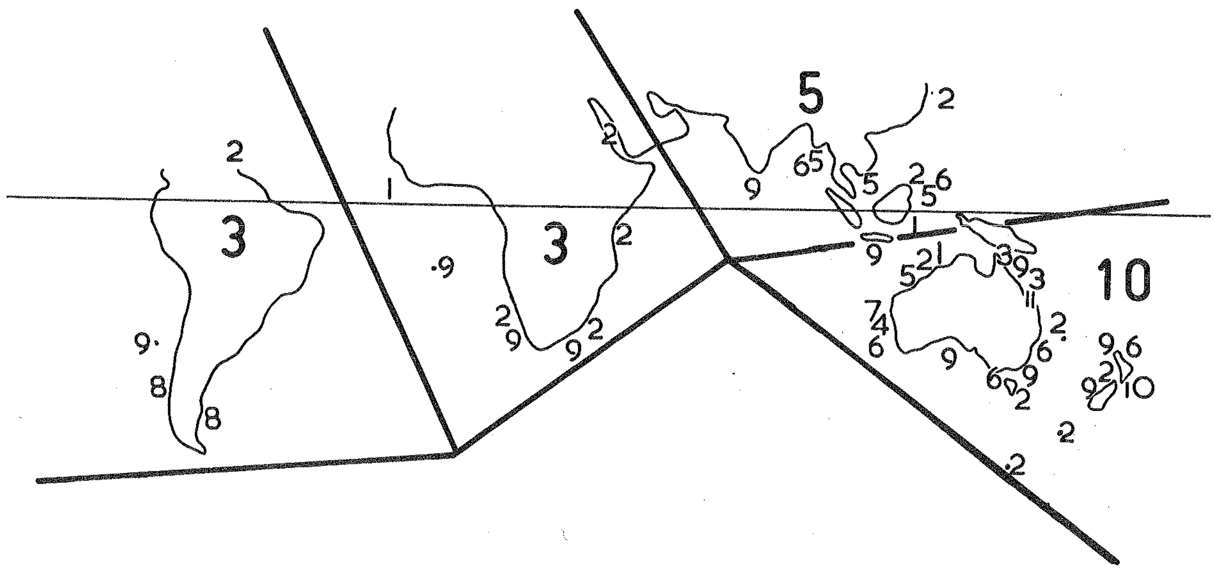
In the following very general account, examples will be given wherever possible. Lines of investigation are indicated under the headings of morphology, reproduction and anatomy, cytology and feeding mechanisms.

Fig.42.

Distribution of the genera of Asterinidae in the Southern Hemisphere, excluding Antarctica.

Large face numbers show the number of asterinid genera known from each area.

KEY. 1. Anseropoda
2. Asterina
3. Disasterina
4. Manasterina
5. Nepanthia
6. Paranepanthia
7. Parasterina
8. Patiria
9. Patiriella
10. Stegnaster
11. Tegulaster.



3
3
5
10

Morphology.

Traditionally superficial morphology has been used to delineate the taxonomic parameters of the Asterinidae. Lack of integrated geographical samples, small samples and now-inadequate field notes have bedevilled the biogeography of the family. Patiriella gunnii, redescribed earlier in this account, warranted a description of six lines from Gray; Asterina burtoni Gray, a four line description. Taxonomic procedure requires the designation of a name bearer, the holotype, whose description is the "type" description. Many asterinids now warrant redescription with, it is hoped, adequate series of supporting "paratype" material from throughout the known range of the species considered.

Small samples and unique holotypes will continue to appear especially in the case of rare forms.

Difficulty arises when species or polymorphic species with extended ranges are considered. Some species, as described, may turn out to be extremes of variation of a population and as more material comes to hand this variation can be measured and related to the ecology and biology of the animal concerned. Recent examples from other groups of Asteroidea are A.M.Clark's work on Nectria (1966) and Shepherd's (1967) revision of Uniophora.

Within the Asterinidae further difficulties appear. Asterina burtoni is known from the Mediterranean, the Red Sea and the Maldive Islands. Asterina anomala H.L.Clark, from N.E. Australia and Lord Howe Island, which in my opinion is probably synonomous with Asterina heteractis H.L.C., shows many similarities to A. burtoni. Examination of material from the aforementioned localities only served to exacerbate the current taxonomic criteria. Variation in spinulation is wide and the table appended shows the information gained (Table IX). The sample is not large enough to provide conclusions but on this basis the animals concerned show enough individual variation to place all the specimens under the same name.

Again mention of calcium metabolism must be made. Until information about the pathways of calcium metabolism under varied conditions are available no logical framework is available on which to base this kind of morphological discrimination.

Under this heading the following general questions may be presented.

a) What controls the pattern, numbers, and form of skeletal elements? If temperature related, or related to calcium availability, does the same animal show a different fascies at different parts of its range?

Spinulation of *A. burtoni* Gray and *A. anomala* H.L.C. - actinal surface.

Collection Number	Oral spines	Suboral spines	Furrow spines	Subambulacral spines	Actinal spines	Inferomarginal spines
1902 . 3 . 13	4 - 5	1 - 3	3	2	1 / 2	< 6
27 - 33	4 - 5	1	3	1	1	< 5
British Museum	5 - 6	1	4	2	1 - 2	< 8
Maldive Islands	5 - 6	1 - 2	3	2	2 - 3	< 8
A. burtoni	5	2	3	2	1 - 2	6 - 8
1965 . 11 . 2	4 - 5	1 - 2	3	2	1	7 - 8
5 - 7	4 - 5	2 - 4	4 - 3	3	1 - 3	< 12
British Museum	5 - 6	1 - 3	4 - 3	3	2 - 3	< 8
Beirut	4 - 5	1 - 2	3	2	1 - 3	5 - 9
A. burtoni	4 - 5	1 - 2	4 - 3	3	1 - 3	< 9

Table IX

Collection Number	Oral spines	Suboral spines	Furrow spines	Subambulacral spines	Actinal spines	Inferomarginal spines
1968 . 8.5	3	1 - 2	4 - 3	2	0 - 1	5
45 - 50	4 - 5	1	4 - 3	2	0 - 1	5 - 6
British Museum	4 - 5	1	4	3 - 2	1	4 - 5
Suez Bay	4 - 6	0 - 2	4	2	0 - 1	6 - 8
<u>A. burtoni</u>	5	2 - 4	4	4 - 3 - 2	1	6 - 7
Tasmanian Museum	4	1 - 2	4	3	1 - 2	<8
Lord Howe Is.	4 - 5	1 - 2	4	4 - 3	2 - 4	<9
	4	2 - 3	4	3	2 - 3	<9
<u>A. anomala</u>	4 -5	1 - 2	4	4 - 3	2 - 3	<8

b) How far does the range of a species extend?

c) Are definable populations present throughout the range?

Reproduction.

A prospectus for the study of reproductive biology of echinoderms has recently been produced by Boolootian (1966). He suggests a minimum frequency of collecting, the kinds of information that should be recorded (e.g. water temperature and salinity). He relates greatest numbers of larvae to gonad biomas's and suggests study of gonad cytology throughout the season.

Reproduction in the Asterinidae is a fruitful field of investigation. Asterina gibbosa and Asterina panceri in European waters have been studied extensively (Bacci 1965) Within the family a great range of methods of reproduction are known and asexual reproduction is common in many forms. In many cases only an indication of reproductive method can be given here but the accompanying list is the most complete that I have been able to construct. In most cases it is assumed that if the species is fissiparous sexual reproduction is not excluded.

The list is hardly complete but some conclusions may be drawn. The genera Patiria, Patiriella, and Paranepanthia do not appear to exhibit fissiparity. Internal development of young, as known, is restricted to Patiriella vivipara; external brooding to Kampylaster. Nepanthia and Asterina include the fissiparous forms known and Asterina

Table X

Species	Range	Sexual	Asexual
Asterina anomala H.L.C.	Australia, Lord Howe Is. to Hawaii	G	F
Asterina atyphada	S. Australia	Dioecious gonophores directed orally.	-
Asterina batheri	Japan	⚥ unbalanced.	-
Asterina burtoni	Mediteranean, Red Sea, Maldives.	G	F
Asterina gibbosa	European seas	⚥ balanced and unbalanced races.	-
Asterina hamiltoni	SubAntarctic	Orally oriented gonopores.	
Asterina pancerii	Mediterranean.	⚥ proterogynous.	-
Asterina pectinifera	Japan	Dioecious - planktotrophic larvae.	-
Asterina scobinata	Australia	⚥ Orally orientated gonopores.	-
Asterina wega	Australia	-	F

Species	Range	Sexual	Asexual
Disasterina lepralacanthia	Australia	Orally oriented gonopores	
Kampylaster incurvatus	Antarctic	Brooding form	-
Nepanthia belcheri	Australia	G	F
Nepanthia brevis	Australia	G	F
Nepanthia briareus	China Sea	G	F
Nepanthia variabilis	Australia	G	F
Paranepanthia grandis	Australia	Dioecious - gonopores directed aborally	-
Patiria miniata	Westcoast, U.S.A.	Dioecious. Planktotrophic larvae	-
Patiriella brevispina	Australia	Dioecious. Aborally directed gonopores	-
Patiriella calcar	Australia	Dioecious. Aborally directed gonopores	-

Species	Range	Sexual	Asexual
Patiriella calcarata	Juan Fernandez Islands	Presumed as above. Only one specimen examined	-
Patiriella exigua	Indo Pacific	Shortened development. Eggs laid on substrate	Fission not proven
Patiriella gunnii	Australia	Dioecious. Aboral gonoduct	-
Patiriella regularis	N.Z. and Tasmania	Dioecious. Planktonic larvae but only swim for a short time	-
Patiriella vivipara	Tasmania	♀ coelomic incubation	-

includes a wide range of hermaphrodite species the details of whose biology are only known in a few cases.

It is interesting to note that Livingstone placed Asterina scobinata close to Asterina burtoni Gray. Perhaps this is another example of speciation by reproductive method at the extreme end of the range of a generic line as the few specimens of A. scobinata available for study were hermaphrodite and the genopores are directed towards the substrate.

Problems arising in Australian Asterinidae include:

a) Complete studies of sexual cycles and cytology of the species of Patiriella especially among closely related forms like Patiriella gunnii and Patiriella brevispina.
b) When material is available a study of the hermaphrodite sexuality of Asterina scobinata (only three specimens are available to me and the only gonad sectioned so far demonstrated very large eggs and a small amount of male tissue).

General questions to be asked are:

1) Does fissiparity depress sexual reproduction, i.e. in Nepanthia and Asterina?
2) Are there stages at which sexual reproduction predominates and others when fissiparity is the most common

mode of reproduction?

3) Do some forms reproduce sexually in some parts of their range and demonstrate fissiparity under other conditions? (e.g. Asterina burtoni)

4) Is there a tendency amongst those forms living in restricted habitats (i.e. under boulders and in coral crevices) to have reproductive patterns where the young are not released into the plankton but remain in the habitat? (e.g. Patiriella vivipara, Patiriella exigua and Asterina scobinata)

5) Are fissiparous individuals variable in symmetry or in embryology, does this occur later, or is it a plastic property of a given species?

6) Can patterns of reproductive isolation be elucidated and can this be correlated with the distribution of known forms?

Anatomy, cytology and feeding mechanisms.

As stated previously some asterinid sea stars are known to exhibit specialised feeding mechanisms with accompanying specialisation of Tiedemans pouches, rectal caeca and the retractor muscle harness of the cardiac stomach.

This author feels that on the state of present knowledge little can be gained from this kind of study as far as taxonomy is concerned.

Specialised feeding may be expressed as morphological colour but specialised feeding as a source of colours observed in life must remain a hypothesis at present.

Questions to be asked are both general and specific.

a) In the case of Patiriella brevispina is the narrow band of latitude in which the species is found reflected in the specialised feeding habits? Alternatively is the purple colouration observed caused because only when feeding on a certain group of foodstuffs is the animal unable to excrete the colour precursors in any other way?

b) Similar questions may be asked of Patiriella vivipara (constantly orange-yellow)and Patiriella calcar (variegated colours).

c) There appears to be a tendency for asterinid sea stars to become more dependant on algal grazing(perhaps aided by mucous sheets). Is feeding related to the size of the species, and the habitat in which both seastar and food are found?

Thus information required to eventually revise the sea star family Asterinidae falls under three main headings.

I. A study of calcium pathways in metabolism to elucidate the significance of plate and spine patterns.

II. A study of reproduction throughout the group to describe reproductive isolation.

III. A study of anatomy and cytology of the digestive system and associated tissues to elucidate parallel evolution within larger groups and interspecific non-competing mechanisms.

Conclusions.

The genus *Patiriella* is a definable taxonomic unit. Six species are known from Tasmania; nine from the Southern Hemisphere. Australia shows the greatest proliferation of species, some with specialised modes of reproduction. Assuming an Indo-Pacific origin for the genus the "*exigua*" forms have dispersed in the low latitudes of the Southern Hemisphere and the "*regularis*" group have dispersed eastwards in higher latitudes.

It is suggested that there may be a tendency for shortened forms of development in species of Asterinidae found in Tasmania - the southern limit of range for the Australian forms. It is also interesting to note that the hermaphrodite asterinids known all have distribution around 40° of latitude north or south (i.e. *Asterina gibbosa* and *Asterina pancerii* in European waters, *Asterina batheri* in Japan and *Asterina scobinata* and *Patiriella vivipara* in Tasmania). It remains to be seen if factors common to these areas could have resulted in the convergent evolution of hermaphrodite forms or whether hermaphrodism is a primitive characteristic of species pushed outwards from a rapidly speciating pool of Indo-Pacific asterinid forms.

ADDENDA.

After preparation of this manuscript further information has emerged that affects various parts of the thesis.

1) Marginaster sp. indet. (p. 11) has now been studied in more detail. The species, of which a description is in press, is not conspecific with A.M.Clark's specimen attributed to Marginaster paucispinus Fisher. The Tasmanian form now becomes the only known littoral species of Marginaster.

2) Plecaster decanus Müller and Troschel has now been recorded from Jacob's Boat Harbour, northern Tasmania. A record of this occurrence has been submitted to press. This record confirms the occurrence of this species on the southern shore of Bass Strait. The species is also known from South Australia to Newcastle, New South Wales (Shepherd, 1968).

These two species now bring the total of species comprising the Tasmanian asteroid fauna to thirty six.

3) Patiriella exigua (p. 51). The distribution of this species is given as Tasmania, South and East Australia and the Indo Pacific

region. Mortensen 1933 is quoted as recording *P. exigua* from St. Helena. The importance of this species as an indicator of epiplanktonic dispersal is noted. In the prospectus presented earlier in this account (p. 132) it is also noted that there is some evidence to support the theory that the species known as *P. exigua* is a polymorphic form.

Since this account was prepared further information has become available. *P. exigua* is noted for its shortened larval development and concommitant with this the gonoducts of the Australian sea star attributed to this species are directed towards the substrate. Samples attributed to *P. exigua* were obtained and the orientation of the gonoducts noted.

The following material was examined.

1) 12 specimens from the Philippine Islands, collected by Dr. A.E. Mearns and determined by H.L. Clark as *P. exigua* (U.S. National Museum No. 38088).

2) 4 specimens from Pelaboean Ratoe, Java, collected by Owen Bryant, Oct. 1909 and determined by H.L. Clark (U.S.N.M. 38003).

3) 12 specimens from Lemon Valley Bay, St. Helena, collected by A. Loveridge and determined by M.E. Downey (U.S.N.M. E9994).

4) 4 specimens from Borneo collected on a research cruise of the "Albatross" in 1908 and determined by W.K. Fisher (U.S.N.M. 40254).

5) 7 specimens from Port Binang, Subic Bay, Philippines from the "Albatross" Philippine Expedition 1907 - 1910 determined by W.K. Fisher (U.S.N.M. 40261).

6) 1 specimen from Aola, Guadalcanal, collected by G. Officer in 1961. Authority for determination is not given (National Museum of Victoria No. H116).

7) 1 specimen from Bora Bora, New Guinae collected by J. Exton in 1891. Authority for determination not given (N.M.V. No. G114).

8) 2 specimens from Airlie Beach, Proserpine, Queensland collected by K. Deacon in 1968. No determination placed on these specimens. Held in the collections of the Australian Museum.

9) 3 specimens from Zamboanga, Philippine Islands. Those specimens carry a museum determination of *P. exigua* (British Museum No. 1890.5.7.581-584).

10) 5 specimens from the Solomon Islands with a museum determination as *P. exigua* (B.M. No. 1968.6.14.156-160).

The second series of specimens (U.S.N.M. 38003) do not belong to the genus *Patiriella* and are probably not asterinids. The remainder match the morphology of *P. exigua* as known from southern Australia in most respects. However, none of the individuals listed above possess actinally orientated gonoducts. On the basis of the material available to me I must now rephrase the distribution of *P. exigua* in the most general terms.

Distribution of *P. exigua*.

1) *P. exigua* (with actinally orientated gonopores) is distributed in Tasmania, Southern Australia and Eastern Australia to about New South Wales and Queensland border. On the basis of one sample available to me (Tasmanian Museum No. H383) this form is also known from South Africa.

2) Specimens of asterinids, most probably belonging to the genus *Patiriella* and matching *P. exigua* in all morphological characters but whose gonoducts are directed abactinally and from throughout the range quoted in the literature have also been studied. On the basis of reproductive habits this author cannot attribute them to that species.

The general implications of this situation have been predicted in the prospectus. More specific implications follow :—

a) Many of the references to *P. exigua* in the key literature must be treated with reservation.

b) The evidence for epiplanktonic dispersal of *P. exigua* becomes weaker though the evidence may still be valid for other forms.

c) The problem of polymorphism or a series of sibling "exigua" forms needs more material for analysis and solution.

d) The distribution of *P. exigua* as stated above needs explanation. It is pointed out here that both regions are cool temperate as defined by Bennet and Pope (1960) and that *Coscinasterias calamaria* is also known to have a similar distribution. H.L. Clark (1923) attributed the presence of the latter species to transportation on ship's hulls.

e) Can the "*exigua*"forms modify their reproductive mechanisms in response to temperature, relative day length or insolation? The suggestion appears unlikely in view of the tolerance of high temperatures shown by *P. exigua* in littoral rock pools.

f) If a series of similar "*exigua*" forms is definable how do they maintain specific isolation and morphological similarity from the cool temperate regions of both Australia and Tasmania to the tropical and sub-tropical areas of the Indo-Pacific?

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Appendices

The following appendices have been removed for copyright or proprietary reasons

Appendix I. New Zealand Marine Animals in Channel Waters. *Tasmanian Fisheries Research*, vol. 1 no. 3 pp4-5 1967

Appendix II. Asterodiscus truncatus (Coleman, 1911), a new record for Tasmanian waters. *Papers and Proceedings of the Royal Society of Tasmania*, 102 . pp. 23-24, 1968 http://eprints.utas.edu.au/14242/

Appendix III. A field key to Tasmanian Sea Stars. *Tasmanian Fisheries Research*, vol. 3 no. 1 pp1-6 1969

Appendix IV. New Zealand Sea Stars in Tasmania. *Papers and Proceedings of the Royal Society of Tasmania*, 103, 53-55, 1969 http://eprints.utas.edu.au/14231/

Appendix V. A viviparous species of Patiriella (Asteroidea, Asterinidae) from Tasmania. *Proceedings of The Linnean Society of New South Wales* 93:294-296 (1969)